



**THE IMPACT OF INTEGRATING SMARTPHONE TECHNOLOGY ON
GRADE 10 LEARNERS' ACHIEVEMENT IN ALGEBRA**

By

TENDAYI MHLANGA

submitted in accordance with the requirements for

the degree of

MASTER OF EDUCATION

in the subject

Mathematics Education

at the

UNIVERSITY OF SOUTH AFRICA

SUPERVISOR: PROFESSOR ANESHKUMAR MAHARAJ

CO-SUPERVISOR: PROFESSOR MONICA JOJO

2018

DECLARATION

Name: Tendayi Mhlanga

Student number: 46254366

Degree: Master of Education in Mathematics Education

Title: The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra.

I declare that "The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra" is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I have not previously submitted this work, or part of it, for examination at University of South Africa (UNISA) for another qualification or at any other higher education institution.



SIGNATURE

22-11-2018.

DATE

ACKNOWLEDGEMENT

I would like to thank my supervisor, Professor Aneshkumar Maharaj, for his commitment, patience, guidance, encouragement and support throughout the study. It was an immense pleasure working with him. I would also like to thank my family and colleagues for supporting me throughout my studies. Lastly, my gratitude goes to the principals, teachers and learners of the two participating schools.

Thank you to my editor, Ms Liza Marx from Academic and Professional Editing Services, for attending to the copy-editing, proofreading and formatting of my study.

ABSTRACT

Smartphone technology can be integrated in mathematics education, since most learners immerse in this technology. Teachers should be facilitators of confined learning in traditional classrooms, including digital facilitators. The aim of the study was to determine the effect of integrating smartphone technology on Grade 10 learners' achievement in algebra. The study focused on two Grade 10 classes from different township schools in the Gauteng Province. The study was conducted during the first term of 2016. A quasi-quantitative experimental research design was used. Smartphones were integrated in algebra teaching and learning, using the Microsoft Math online application: <https://www.math.microsoft.com>. Despite challenges encountered during the study, the results indicated a positive impact on learners' achievements in algebra, amongst experimental group learners. A need exists for future research in integrating smartphone technology in mathematics education.

KEY TERMS: Smartphone technology, online, application, Microsoft Math, digital facilitators, quasi-quantitative, website, mathematics education, learner achievement, traditional classrooms, algebra

TABLE OF CONTENTS

DECLARATION	ii
ACKNOWLEDGEMENT	iii
ABSTRACT	iv
TABLE OF CONTENTS	v
LIST OF TABLES	viii
LIST OF FIGURES	ix
ABBREVIATIONS	x
CHAPTER 1: INTRODUCTION AND OVERVIEW	1
1.1 Contextual background of the study	1
1.2 Rationale	2
1.3 Purpose and anticipated outcomes of the research	4
1.4 Problem statement	4
1.5 Aim and objectives	6
1.5 Research questions.....	6
1.7 Definition of terms	7
1.8 Overview and division of chapters.....	8
CHAPTER 2: LITERATURE REVIEW	9
2.1 Introduction	9
2.2 Appropriateness, effectiveness and usefulness of smartphones.....	10
2.3 Free mathematics mobile applications	15
2.4 Teaching and learning methods with smartphone integration	19

2.4	Learning styles when smartphones are integrated	21
2.5	The independence of learning using smartphones.....	22
2.6	Challenges of using smartphones of using smartphones as teaching and learning tools.....	23
2.7	Conclusion	24
CHAPTER 3: THEORETICAL AND CONCEPTUAL FRAMEWORKS		26
3.1	Introduction	26
3.2	TPACK	26
3.3	AT.....	31
3.4	Conclusion	33
CHAPTER 4: RESEARCH DESIGN.....		34
4.1	Introduction	34
4.2	Research methodology	34
4.3	Data analysis.....	37
4.4	Validity and reliability.....	38
4.5	Ethical considerations	39
4.6	Conclusion	41
CHAPTER 5: DATA ANALYSIS, FINDINGS AND DISCUSSION		42
5.1	Introduction	42
5.2	Organising and summarising data.....	42
5.3	Findings and discussion	55
5.4	Summary.....	62
CHAPTER 6: CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS		64
6.1	Introduction	64

6.2	Conclusion	64
6.2.1	Effectiveness of smartphone technology in providing support	65
6.2.2	Teaching and learning methods, and learning styles	65
6.2.3	Appropriateness of smartphone technology	66
6.2.4	Usefulness of smartphone technology to provide support material... ..	66
6.2.5	Impact on independence of learners, using smartphones	67
6.2.6	Challenges of integrating smartphone technology	68
6.3	Recommendations	69
6.4	Limitations	69
REFERENCE LIST		71
APPENDICES		76
Appendix A: Permission request from the Gauteng Department.....		76
Appendix B: Permission request from School A principal		78
Appendix C: Permission request from secondary school B principal		80
Appendix D: Correspondence seeking permission from mathematics teacher .		82
Appendix E: Correspondence seeking permission from mathematics teacher .		85
Appendix F: Permission request from parent/guardian at secondary school A .		88
Appendix G: Permission request from parent/guardian at School B		91
Appendix H: Permission request from learner participant at school A		94
Appendix I: Permission request from learner participant at school B		98
Appendix J: Pre-test and post-test with memorandum.....		102
Appendix K: Examples of online activities done by the experimental group....		114

LIST OF TABLES

Table 1.1: End of Term 1, 2015 algebra results	5
Table 2.1: Free websites.....	16
Table 5.1: Algebra pre-test marks for the control group.....	43
Table 5.2: Algebra pre-test marks grouped frequency distribution table	44
Table 5.3: Algebra post-test marks for the control group	45
Table 5.4: Algebra post-test marks grouped frequency distribution table ..	46
Table 5.5: A paired samples dependent pre- and post-test marks	47
Table 5.6: Algebra pre-test marks for the experimental group	488
Table 5.7: Algebra pre-test grouped frequency distribution table	49
Table 5.8: Online marks and percentages for learners	511
Table 5.9: Algebra post-test marks for the experimental group.....	522
Table 5.10: Algebra post-test marks for the experimental group.....	533
Table 5.11: A paired samples dependent pre- and post-tests marks.....	54
Table 5.12: Algebra online and post-test marks.....	59

LIST OF FIGURES

Figure 3.1: The technological pedagogical content knowledge model 30

Figure 5.1: The control group’s pre-test marks (n = 30) 555

Figure 5.2: Control group’s post-test marks (n= 30) 566

Figure 5.3: The experimental group’s pre-test marks (n= 30)..... 57

Figure 5.4: Experimental group’s post-test marks (n=30)..... 58

ABBREVIATIONS

AT	Activity theory
ATP	Annual Teaching Plan
CAPS	Curriculum Assessment Policy Statement
CK	Content Knowledge
GDE	Gauteng Department of Education
GCSE	General Certificate of Secondary Education
ICT	Information and communication technology
LTSM	Learning and Teaching Support Materials
MEC	Minister of Executive Council
PCK	Pedagogical Content Knowledge
PK	Pedagogical Knowledge
SA	South Africa
SML	Self-Management of Learning
TCK	Technological content knowledge
TK	Technological Knowledge
TPACK	Technological pedagogical content knowledge
TPK	Technology pedagogical knowledge

UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNISA	University of South Africa

CHAPTER 1: INTRODUCTION AND OVERVIEW

1.1 Contextual background of the study

Emerging and current technological devices, such as desktop computers, laptops, tablets and smartphones are influencing teaching and learning methods, strategies and mathematics content styles (Gunter & Gunter 2015). It is important that mathematics teachers change their pedagogies of teaching to keep pace with technological developments and societal expectations (Hoffman & Pearson's study, as cited in McMillan & Schumacher, 2010). Lu (2012) also supports this argument that mobile technologies, such as smartphones, are dramatically changing the ways of teaching, learning and social interaction. These technologies may be used as powerful devices for increasing access to quality digital mathematics education, enhancing academic achievement. In addition, learners who are digital natives, learn differently from their predecessors or digital immigrants (Rikhye, 2009).

The digital natives are interested in using technologies, such as smartphones in their day-to-day activities. According to Gunter & Gunter, (2015) specialists in educational technologies predicted that most learners would be using smartphones in their formal and informal educational experiences. These technologies can be harnessed to enhance teaching and learning of mathematics content, such as algebra. Most mathematics teachers use non-technological pedagogies in this digital era, yet learners are exposed to mobile smartphone technology daily. These smartphones can be used for mathematics teaching and learning purposes by the learners for improved achievement.

The mathematics teacher should involve learners in their own learning. This may be conducted by attracting their interest and creating a conducive learning environment (Woolfolk, 2010). For the benefit of learners, smartphone technology can be integrated in teaching and learning mathematics content to capture their interest and attention, since they always immerse this technology.

Most township schools in the Gauteng Department of Basic Education (GDE) Province in South Africa (SA) do not have enough desktop computers, laptops and tablets for all the learners. Allowing smartphones is more cost effective for integrating information and communication technology (ICT) in teaching and learning mathematics content. In a digital society, educational technology is being encouraged in teaching and learning mathematics. Mobile handheld technologies, such as smartphones, are popular, compared to desktop computers, laptops and tablets, as they offer numerous opportunities for anytime and anywhere learning (Traxler, 2010). Significant differences exist between desktop computers and mobile smartphone technologies. Traxler (2010) further defines a desktop computer as bound to limited time, and confined to places, such as the classrooms. Social isolation can be created, whilst smartphone technologies can be used in times and places for the learners. He also argues that a few individuals use desktop technologies, whilst smartphone technologies operate globally. In addition, smartphone handheld technologies integrate collaboration, learner-centred and independent learning.

Effective teaching and learning of mathematics should incorporate the above-mentioned approaches. Smartphones have functions and features that are found in desktop computers, laptops and tablets. These are the main common ICT educational devices. It may be convenient to integrate smartphones into teaching and learning mathematics as technological devices to promote ICT mathematics education in a technological society.

1.2 Rationale

The schools where the study was conducted are in township residential areas in the (GDE) Province in SA. The Gauteng Minister of Executive Council (MEC) of Education is hoping to dispose of conventional classroom learning and teaching support materials (LTSM), such as chalkboards, replacing them with the latest technologies, such as smart boards, white boards, computers, smartphones and tablets. These would enhance teaching and learning in schools (Teacher reporter,

2016). Most learners at these schools use their smartphones for the traditional purposes of making calls, texting, WhatsApp messages and playing games. They also use them to access social media. The potential benefits of using smartphones for teaching and learning mathematics may be numerous.

At the schools where the study was conducted, policies do not allow learners to bring cellular phones to school. Teachers and parents fear that learners may visit inappropriate websites and post various incidents happening at the school on social media during school hours. The reality is that most learners always bring these devices to school. Instead of totally banning them, it is better to use them for teaching and learning mathematics content (Ormiston, undated).

The study schools are subsidised by the government mainly because they are in the former disadvantaged township communities. However, some of the learners' parents and guardians have good jobs. It may be expensive for schools to provide a desktop computer, laptop or a tablet to each learner to integrate ICT in teaching and learning mathematics topics, such as algebra. The best option for learners to learn algebra may be to use smartphones. Smartphones are becoming popular amongst the learners. They are also affordable and portable. In South Africa, a cheapest smartphone costs about three hundred and forty-nine rand (R349). It is common knowledge that smartphones are affordable by people who stay in townships. Teaching and learning is not restricted to desktop computers anymore, but a variety of useful materials may be accessed through multi-devices platforms, such as smartphones (Online Learning Consortium, 2015). As indicated previously, smartphones hold functions and features, the same as those on desktop computers, laptops and tablets (Charamba, 2015). Their integration for teaching and learning purposes may promote the use of ICT in mathematics education, with a positive impact on learners' achievement.

1.3 Purpose and anticipated outcomes of the research

The purpose of this study was to determine if integrating smartphone technology into algebra teaching and learning to Grade 10 learners would have an impact on their academic achievement.

Integrating smartphone technology into the teaching and learning of algebra to Grade 10 learners was expected:

- to offer alternative opportunities in using smartphone devices to access quality mathematics education to learners who cannot access desktop computers, laptops and tablets;
- to motivate learners to learn mathematics which is normally viewed as a difficult, abstract and boring subject; and
- to assist learners' achievements in algebra.

1.4 Problem statement

Most Grade 10 learners at schools where the study was conducted, own smartphones they use for non-educative purposes in their day-to-day activities that could assist in the technology era where integrating ICT educational devices are being promoted in teaching and learning mathematics content. These smartphones can be integrated for teaching and learning mathematics purposes to the 21st century learners, since they hold functions and features of other educational technology. The learners were non-performing in algebra, maybe because of the non-technological pedagogies that the mathematics teachers use. In the Grade 10 mathematics syllabus, it is important for learners to master algebra before accomplishing other topics, such as trigonometry, geometry, statistics, functions, financial mathematics and probability. These topics use algebra as a base. Integrating smartphone technology may have a positive impact on learners' achievement in algebra.

Table 1.1 indicates the end of term 1, 2015 algebra results of the Grade 10 learners at school A and school B where the research was conducted.

Table 1.1: Algebra results of the learners from Schools A and B

Descriptors as percentages	Levels	School A Candidates	School B Candidates
80-100	7	0	0
70-79	6	0	0
60-69	5	0	0
50-59	4	10	16
40-49	3	20	18
30-39	2	30	25
0-29	1	51	30

From Table 1.1, only 26 learners out of 200 learners got 50% and above. Only 13% of all the learners in Grade 10 in 2015 doing mathematics at the study schools, got 50% and above in the algebra test. This was a low pass rate. The study integrated smartphone technology into algebra teaching and learning to determine the impact of the technology on the learners' achievement.

1.5 Aim and objectives

Aim

The aim of the study was to determine the effect of integrating smartphone technology on Grade 10 learners' achievements in algebra.

Objectives

During the conclusion of the study, Grade 10 learners were expected to use mathematics applications and websites in learning algebra; to use knowledge of smartphone technology to enhance learning in algebra; to utilise smartphones as technological devices in learning algebra; and to identify effective learning skills integrating smartphones.

1.5 Research questions

The study was guided by a main research question and four sub-questions.

Main question

The main research question was "How does integrating smartphone technology into algebra teaching and learning have an impact on Grade 10 learners' achievement?"

Sub- questions

The study's sub-questions were:

- How does smartphone technology affect the teaching and learning of Grade 10 algebra?
- How smartphone technology can be appropriate, effective and useful in teaching and learning of Grade 10 algebra?
- What is the impact on independence if smartphone technology is integrated into algebra teaching and learning?
- What are the challenges of integrating smartphone technology into teaching and learning of Grade 10 algebra?

1.7 Definition of terms

Certain terms used in the study are defined below:

- data analysis and discussion of the findings. Chapter 6 is about the conclusion Mathematics education is teaching and learning mathematics (Polly, 2015);
- Digital natives are individuals who were born after technology and are growing up in the technological era (Rikhye *et al.*, 2009);
- Digital age is the era that individuals spend most of their time using computers, video games, digital cameras and music players, video cams, cell phones, internet and tablets (Prensky, 2001);
- Digital immigrants are individuals who were born prior to technology but have at a later stage in their lives, became interested and adopted certain aspects of the new technology (Prensky, 2001);
- Digital divide is a split between access to technologies between individuals from disadvantaged communities and the rich (Woolfolk, 2010);

- Smartphones are mobile cellular phones with functions and features of desktops computers, laptops and tablets;
- technophobia is the fear to integrate technology in teaching and learning;
- social media is an internet-based form of communication, it is about the integration, collaboration and interaction of individuals to speak, to share information and to create web contents (Rastogi, 2015); and
- 24/7 is about accessing mathematics content 24 hours daily, for seven days a week.

1.8 Overview and division of chapters

The research project comprised six chapters. Chapter 2 comprises a literature review. It deals on aspects, individuals are indicating on integrating smartphone technology in teaching and learning certain mathematics topics. Chapter 3 concerns theoretical and conceptual framework. It explains theories and concepts, related to the study. The conceptual framework is used to guide the researcher. Chapter 4 concerns the research methodology. This included the research design, data collection and intervention programme. Chapter 5 is about research results, recommendations and limitations on the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Smartphone mobile technology changes the educational system, closing the learning digital divide by providing SA learners access to mathematics tuitions on their smartphones, anytime and anywhere (Roberts & Vanska, 2011). Learners may use their mobile smartphones as learning technological devices. Most learners in disadvantaged communities in the (GDE) in SA, do not have access to desktop computers, laptops and tablets as (ICT) educational technology devices in mathematics, yet ICT in mathematics education is being encouraged in this technological era.

According to West and Chew (2014), certain learners do not read and study because they do not have textbooks, but smartphones and cellular networks are changing a scarce resource into abundance. This implies that learners can use their smartphones as textbooks where they can access educational information in mathematics 24/7. West & Chew (2014) indicated that, in a survey conducted by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) in partnership with Nokia and the World Reader, to investigate the habits, preferences and attitudes of mobile smartphones readers in Ethiopia, Ghana, India, Kenya, Nigeria, Pakistan and Zimbabwe, it was found that individuals study and read more when using their smartphones. It emerged from the survey that individuals who disliked reading and studying developed a positive attitude. The findings of this survey can also apply to mathematics, viewed by many individuals as a boring, abstract and a difficult subject.

This literature review focuses on: appropriateness, effectiveness and usefulness of smartphone technology; free mathematics mobile applications and websites; teaching and learning methods; learning styles; independence learning; and

challenges encountered by teachers and learners in integrating smartphones for teaching and learning purposes.

2.2 Appropriateness, effectiveness and usefulness of smartphones

Literature indicates that in 2008, more individuals used smartphones, compared to those who used desktop computers globally (Niazi's & Mahmoud's study, as cited in Gourava 2013). Even in developing countries, such as SA, smartphone use increased significantly. Smartphones are the most widespread and accessible ICT devices in SA, especially amongst the younger generation in urban, semi-urban and rural areas (Ford's & Botha's study, as cited in Roberts 2015). This implies that most learners' parents and guardians in formerly disadvantaged communities of SA may afford to buy smartphones, either on prepaid or on contract terms.

These smartphones may be used as devices for teaching and learning mathematics at secondary level. In addition, these devices may provide numerous opportunities to digital native learners. For instance, according to Sampson (2013), smartphones enable learners to interact with others over the phones or the internet; to browse online content; to download text, images or movies; to play games and music; to watch films; and to obtain navigation assistance. The above, indicate that smartphones are essential technological devices for the learners' everyday lives and may be utilised in mathematics education.

Smartphones may be considered as important devices in mathematics education to the learners, using them widely and daily. These smartphones are popular amongst mathematics learners because they are affordable and portable (Sampson, 2013). That author further indicated that smartphones have the potential of increasing access to quality digital mathematics content in secondary schools, motivating learners to spend more time on mathematics tasks, and assisting secondary school learners to improve their mathematics results.

In addition, smartphones may promote mathematics learning during school hours and after hours (UNESCO's study, as cited in Batista & Barcelos, 2014). Another advantage of using smartphones is that learners do not need to carry heavy mathematics textbooks whenever they want to learn mathematics.

In the SA Curriculum Assessment Policy Statement (CAPS) for mathematics, learners are supposed to do classwork and homework activities daily. Certain learners do not do homework after school because of a lack of mathematics textbooks. If smartphones are integrated as teaching and learning devices, most learners can be expected to do their homework, since these devices may replace textbooks.

(Ndafenongo's study, as cited in Batista & Barcelos, 2014) reported that in Grahamstown, in SA, smartphones were used to teach the Pythagorean Theorem by distributing videos to learners' mobile smartphones. The smartphones were used in learning and teaching situations to support the understanding of the concept. (Ndafenongo's study, as cited in Batista & Barcelos, 2014) further, reported that the use of video clips resulted in improved learner achievement, engagement, attention and concentration during the lessons, content delivery development improvement, collaboration, interaction and independent learning of mathematics. The results also indicated that smartphones may be used to support teaching and learning in schools with inadequate teaching and learning technological resources. The Microsoft Math used in the study, was also expected to contribute to the above-anticipated outcomes.

Mzekandaba (2013) indicated an increasing interest in using smartphone technology in teaching and learning mathematics content in SA. For example, the then Vice President of Nokia South and East Africa launched the Nokia Mobile Mathematics pilot in 2009 after a request by the then Deputy President of SA to establish how learners could use smartphone technology to facilitate learning and teaching. This mobile mathematics provided teachers with the ability to understand their learners' competence and areas of improvement.

Mzekandaba (2013) further, indicated that smartphone mobile services holds the potential of making educational technology affordable and cheap; of not putting too much pressure on computer infrastructure in schools; of bringing mathematics into the social networking, used by the learners in their lives; and of promoting independent learning.

According to the Nelson Mandela Metropolitan University (2013) in Eastern Cape, SA, for a number of years, the Govan Mbeki Mathematics Development Unit at the Nelson Mandela Metropolitan University combined with the Association of Mathematics Educators in South Africa, Eastern Cape Province, successfully promoted integrating mobile systems, such as smartphones. These assisted with teaching and learning mathematics. A successful pilot project was done exclusively on the MXIT Private Limited application for Grade 9 and 11 mathematics learners in the province. The project structured CAPS syllabus, with objective mathematics questions, completed by learners on smartphones that assisted on their academic achievement. The Microsoft Math used in the study, included activities, captured in the CAPS syllabus.

In January 2015, Vodacom SA launched its own education portal, called Vodacom e-school at the Department of Basic Education's top achievers in the 2014 National Senior Examinations' breakfast event (Vodacom, 2015). The Vodacom e-school includes all subjects from Grade 4 to 12 of the SA Curriculum. According to Vodacom (2013), the Vodacom e-school project is in line with Vodacom's ongoing process to provide educational (ICT) devices, such as smartphones, tablets and internet accessibility to learners in disadvantaged communities.

These smartphones may be used to support teaching and learning in this digital era. Learners are required to login onto the Vodacom e-school website, www.mytopdog.co.za/vodacom and then observe video lessons, read examples, theory, study tips, and do online-based interactive tests on the SA CAPS syllabus. This may assist them in achieving better results. Learners are free to track their

progress and see how they performed academically, compared to their peers, in a fun, easy and friendly manner.

The main aim of Vodacom is to provide basic devices, such as smartphones and tablets at affordable prices to assist enhancing learners outside school. This may increase learners' time on tasks, indicating, learners may spend more time doing educational activities on their smartphones and tablets. This crucial factor may enhance learner achievement in mathematics. The Microsoft Math, as Vodacom e-school, had CAPS aligned questions that learners answered online and saw how they performed, compared to other learners in a fun and friendly way. They also received instant feedback. The feedback assisted the learners with their corrections.

Honikman (2016) noted that a learner at Wynberg Boys High School in SA improved his performance in pure mathematics from 38% in preparatory matric test of 2015 to 69% in the final examination of the same year. He spent every day of the school holidays perusing past matric papers in pure mathematics and watching a video on each question on his smartphone. He accessed the videos on www.PaperVideo.co.za. This same author further indicated that learners at Spine Road High School in Mitchell's Plain in SA started using Paper Video on their smartphones. During the 2015 matric results, the school achieved a 96% pass rate in pure mathematics.

According to Charamba (2015), Econet Mobile Wireless Zimbabwe launched a digital learning platform, called Ruzivo online. This learning platform can be accessed online: www.ruzivodigitallearning.co.zw, using smartphones. It is an online interactive application aiming to assist primary and secondary pupils in Zimbabwe to improve their performance. Ruzivo online platform like Microsoft Math developed digitalised academic content in all subjects in the Zimbabwean syllabus, including interactive lessons, exercises and tests conducted by the learners on their smartphones.

Batista and Barcelos (2014) indicated that in Trinidad and Tobago a MobileMath application was used to teach elementary algebra in various secondary schools for a period of three months. The application comprised lessons, examples, tutorials, quizzes and activities in algebra, accessed using smartphones. Using the application caused great improvement in the learners' achievement in algebra. However, the learners, who benefitted more, were those revising the topic (Batista & Barcelos, 2014). This means that the MobileMath application was used for revision purposes and expanded opportunities. The Microsoft Math application used in this study was similar to the MobileMath application as it was used mainly for revision purposes and expanded opportunities.

A study in Spain on the use of mobile technology devices, such as smartphones in the teaching and learning situations, indicated that their use might contribute to:

- social and academic equity amongst learners of various backgrounds;
- reduction of inequalities in learners' academic achievements, irrespective of their socio-economic status;
- improving performance of those learners, academically challenged;
- the motivation of learners during formal lessons and
- the bridging of the digital divide (Sampson *et al.*, 2013).

Sampson *et al.* (2013) indicated that the same study also revealed that the learners, who benefitted more, were those from disadvantaged socio-economic and cultural backgrounds. This study occurred at township schools where most learners were from former disadvantaged families.

Another study in the United Kingdom (UK) indicated that learners preferred to use mobile technologies, such as smartphones for educational purposes, instead of hardcopy textbooks (Dearnley, as cited in Sampson *et al.*, 2013). The Gauteng MEC for Education in SA advocates for paperless classrooms. This implies that most learners in the province may be accessing most educational information through technological gadgets. There may be no need to carry heavy textbooks to and from

school. Studies also indicated that in a study that compared the usage of mobile technological devices, such as smartphones and laptops in small group collaborative learning activities, indicated that learners preferred using mobile devices, such as smartphones to laptops (Dearnley *et al.*, as cited in Sampson *et al.*, 2013).

According to Meek (2015), most learners of Onslow County Schools in North Carolina in the United States of America, did not have access to computers connected with internet. Qual Comm provided these schools with smartphones through a project, called Project-K Nect. The smartphones were used for algebra and geometry teaching and learning in economically challenged schools. After the project completion, there was a great improvement in the learners' achievement in mathematics. Smartphones were integrated in algebra teaching and learning to Grade 10 learners from former disadvantaged township schools in the study.

(Walls & Rogers's study, as cited in Polly, 2015) indicated that applications might be integrated in teaching and learning to improve learners' achievement in mathematics. They further indicated that when learners are learning in the classroom, the teacher provides them helpful, timely and accurate feedback. This is also applicable when learning with applications. Applications also provide meaningful and helpful immediate feedback. They allow learners to request assistance or an explanation when they cannot answer a question or cannot progress to the next level on their own (Fallon, Keren & Kolb's study, as cited in Polly, 2015). This was evident in the Microsoft Math application used in the study.

2.3 Free mathematics mobile applications

Numerous free mobile mathematical applications are available in SA that can be downloaded on smartphones (Macmillan Teacher Campus, 2014). These applications may have a positive impact on learners' achievements, if they are properly integrated in teaching and learning the mathematics content. Macmillan Teacher Campus (2014) provides the free websites indicated in Table 2.1.

Table 2.1: Free websites

Website	Activities and Resources
www.everythingmaths.co.za	Everything maths is on the Siyavula website found online with interactive textbooks with grades 10-12 CAPS content that can also be downloaded and printed for free. Learners can watch videos online.
www.mathsandscience.com/	Maths and Science marketing aims at providing excellence in Mathematics and Science teaching and learning by providing materials, methodologies and other information free. Learners from Grades 1 to 12 can download textbooks and videos on smartphones. The Actuarial Society of SA sponsors the website and materials.
www.mindset.co.za./learn	The mindset website has content in mathematics aligned with CAPS syllabus. The website has videos

Website	Activities and Resources
	lessons and revision activities that can be accessed through smartphones.
www.mathsatsharp.co.za/	The mathematics sharp website has worksheets, exam questions and study guides for CAPS syllabus.
www.mathsexcellence.co.za/	Hardworking and dedicated SA mathematics teachers established the mathematics excellence website. Their objective is to improve the standard of mathematics education and make mathematics more accessible to all SA learners. The website is dedicated for teachers to debate issues that affect them and their learners. They can share ideas and LTSM. This helps them to be effective in their teaching.
www.geogebra.org/	Geogebra is a free online educative and dynamic mathematics software for all levels of mathematics content that includes geometry, algebra,

Website	Activities and Resources
	tables, graphs, statistics and calculus in one easy to use package.
www.dessci.com/en/products/mathtype/	Mathtype is an excellent useful interactive equation editor for Windows and Macintosh that helps in creating mathematical notation for word processing, web pages, desktop publishing, presentations and eLearning.
www.mathsdoctor.tv/	Macmillan Science and Education manage mathematics doctor. It provides a lot free interactive worksheets and videos. It is aligned to the UK, General Certificate of Secondary Education (GCSE) and Advanced Level. It is easy to use and it helps in finding relevant mathematics topics under algebra, statistics, numbers and shapes and numerous others mathematics topics.
www.khanacademy.org	Access a library of videos and activities covering K-12 math and

Website	Activities and Resources
	science topics and learning devices to assist students study mathematics.
www.education.gov.za	Learners and teachers can download past examination papers and exemplar papers.
www.thutong.doe.gov.za	Learners and teachers can access past examination papers and lesson plans on the websites.

In the study, a Microsoft Math free application was integrated in teaching and learning algebra. The application was accessed on:
<https://www.math.microsoft.com>.

2.4 Teaching and learning methods with smartphone integration

Activity-based, problem-based, collaboration, distance and learner-centred education can be integrated with smartphone technology (Lu, 2012).

Activity-based

In activity-based learning, learners become actively involved in their own learning (Polly, 2015). The use of smartphones with Microsoft Math online, promoted this type of learning since learners were engaged in the algebra activities.

Problem-based

A goal in teaching and learning mathematics is to promote problem-solving and critical skills amongst learners, living in communities with hardships, economic, political and social challenges (Lu, 2012). These learners must be good decision-makers. On the Microsoft Math activities, learners were provided with challenging projects that they read and understood prior to working with them. Learners read the hints, examples, theories and watched videos before they solved the challenges. The teacher's role was to guide them in solving the challenges.

Collaboration

Microsoft Math promotes collaboration learning amongst the learners (Microsoft, 2016). Collaborative learning encourages small groups of learners to work together to achieve a common goal. In Microsoft Math activities, learners can form online study groups and observe how each group member performs, in a fun and friendly way.

Learner-centred

Integrating smartphones in teaching and learning mathematics, promotes learner-centred education where the teacher facilitates, guides, and mediates learning.

By integrating the above methods, using smartphones, teaching and learning mathematics becomes an active process where learners learn by performing in a collaboration way. As mentioned in Chapter 1, learners become involved in their own education through active learning. Dennis (2015) indicated that mathematics education has shifted from teacher-centred to learner-centred.

Distance education

Distance education is defined as established methods or processes for teaching numerous learners, located at various places, physically separated from the school, their teachers and other learners (UNISA, 2008). Distance education signifies any form of teaching and learning where the teacher and learner are not in the same place at the same time. Integrating smartphones in teaching and learning mathematics, promoted distance education since teaching and learning was beyond the fixed traditional classroom. Learners learnt anywhere and anytime distanced from the teacher. They were able to regulate their own learning. Certain learners worked independently.

2.4 Learning styles when smartphones are integrated

According to Chen (2015), learners use various styles to study mathematics. It is important for mathematics teachers to incorporate the learners' individual learning styles for online teaching and learning with smartphones. This study focused on auditory, visual and kinaesthetic learning styles. This implies that online mathematics teachers need to present information, using all the learning styles to cater for different learners.

Auditory learners

In this study, auditory learners received information by listening to discussions. They listened to videos on algebra on their smartphones. They also discussed certain algebra sub-topics on the Microsoft Math website in their individual groups.

Visual learners

The learners learnt from seeing and reading. They read theory, examples and questions and watched video recordings and interactive mathematical diagrams and graphs.

Kinaesthetic learners

The kinaesthetic learners are interested in touching and moving around. During the Microsoft Math activities, the learners used their hands to type the answers and submit them for assessment online.

The Microsoft Math that the learners used in the study, provided for individual learning styles.

2.5 The independence of learning using smartphones

Integrating smartphones in teaching and learning mathematics positively influence independent learning or the self-management of learning (SML) (Huang *et al.*, 2014). The SML refers to the extent that learners feel they are self-disciplined to attain and engage in autonomous learning experiences.

The SML is similar to autonomous, self-directed, self-regulated and independent learning (Regan's study, as cited in Huang 2014). The learners were involved in their own learning environment outside the classroom. (Regan's study, as cited in Huang *et al.*, 2014) further, suggested that independent learners are expected to:

- improve their performance in mathematics,
- succeed in tertiary education,
- succeed in life expectations in general and
- fit well into the job market.

Independent learners are also motivated to learn and achieve an improved self-esteem. Meyer (2008) indicated that a comprehensive school in the UK achieved a 100% pass rate, obtaining A to C grades in at least five subjects in the GCSE, because of developing independent learning skills across the whole school.

These authors also indicated that a study in the Netherlands identified that students in self-regulated learning environments, are more motivated to learn. They are more actively involved in their own learning than those students who study in restrictive environments. This factor may contribute to improved academic achievement. In SA, independent learners are more likely to succeed during their tertiary education, as they can manage their own studies.

2.6 Challenges of using smartphones of using smartphones as teaching and learning tools

Cellular phones have an adverse reputation in schools. The situation is changing (Ormiston, undated). He argued that, instead of banning cellular phones, they could be used for teaching and learning purposes instead.

The National Council for Curriculum and Assessment in Ireland reached Phase 3 of interesting experiments using cellular phones as teaching and learning devices at numerous schools in Ireland (Wylie, 2015).

Schools in numerous countries hold policies, prohibiting learners from conveying cellular phones (Lu, 2012). They believe that cellular phones affect teaching and learning negatively. This policy, banning cellular phones into schools, also applies to most SA schools, including at the schools where the research study was conducted.

Numerous challenges need careful consideration when using smartphones as teaching and learning devices (Sampson *et al.*, 2013). Challenges mentioned by those authors include:

- expensive cost of communication,
- limited software,
- loss of assessment data,
- long time to enter data to connect to the internet,
- smartphones with small screen sizes,
- limited processing power and memory,
- reduced input capabilities and
- smartphones with low battery life span.

Most traditional teachers experience technophobia, indicating that they are afraid to integrate mobile technology devices, such as smartphones in teaching and learning mathematics (Polly, 2015). These teachers lack training on the use of smartphones as teaching and learning tools.

Certain Education Ministries, Teachers' Unions, parents, principals and teachers aggravate the situation by not supporting smartphone mobile learning, especially for formal lessons. Technology remains. A shift of awareness, embracing this technology is needed, to benefit the learners who are digital natives.

2.7 Conclusion

Smartphones may be integrated into teaching and learning mathematics as appropriate, effective and useful technological devices. Teachers and learners may use free mathematical mobile applications through their smartphones. Various teaching and learning methods and styles may be incorporated when smartphones are integrated as mobile technologies. Teachers and learners may encounter

challenges though, when smartphones are integrated into teaching and learning mathematics.

CHAPTER 3: THEORETICAL AND CONCEPTUAL FRAMEWORKS

3.1 Introduction

The technological pedagogical content knowledge (TPACK) conceptual framework and the activity theory (AT), provide knowledge representation and concept development for teaching and learning with mobile smartphones (Angeli & Valanides, 2015). The TPACK assists the teacher to use digital mobile smartphone technologies to solve the challenges that the learners encounter when learning specific mathematic topics. These include algebra. The AT explains how the topics are to be learnt.

According to Angeli & Valanides (2015), the AT identified objects, mediating devices, rules and the community as part of activity settings, contributing to TPACK development in algebra teaching and learning.

3.2 TPACK

(Mishra's and Koehler's study's, as cited in Angeli & Valanides 2015) suggested a TPACK conceptually framework, concerning the knowledge related to smartphone technology, pedagogy and content. The study used smartphones as technological devices for knowledge and concept development in algebra teaching and learning content in the CAPS curriculum for Grade 10 learners.

Technological knowledge (TK)

TK requires that teachers and learners should be acquainted with the use of smartphones in algebra teaching and learning when using the Microsoft Math application. The smartphones were used to access Microsoft Math online. The Microsoft Math website is <https://math.microsoft.com>. Learners and teachers could

use browsers: Internet explorer; Firefox; Mozilla; Safari and Google Chrome. The Windows 8.1 application could be used offline.

The Windows 8.1 application could be downloaded when using Nokia or Microsoft smartphones only online. To use the Microsoft Math application, learners had to create a Microsoft Math account by signing up with their individual username and password. When learners needed to use Microsoft Math, they signed in to their account with their Microsoft Math details

The teacher created an online group for the learners, signifying the experimental group. As soon as the group was created, an invitation key was generated for the learners to join the group. Teachers and learners were required to be technological literate and to understand the mobile smartphone technology. Mobile smartphone technological literacy was a precondition for effective use of mobile smartphone technology for algebra teaching and learning for Grade 10 learners.

Content knowledge (CK)

CK included knowledge to learn and teach algebra. In the Grade 10 CAPS curriculum, algebra must be learnt and taught in mathematics. The Annual Teaching Plan (ATP) for Grade 10 comprises this topic, forming the base of all topics to be taught and learnt in the further education and training phase. The same topic is also included in the Microsoft Math website: (<http://math.microsoft.com>), used in the study. The mathematics teacher should have a good mathematical content background of algebra to effectively integrate mobile smartphone technology into teaching and learning of algebra to Grade 10 learners.

Pedagogical knowledge (PK)

According to Angeli & Valanides, (2015), the PK comprised a wide and deep knowledge concerning methods, theories, styles and strategies of algebra teaching

and learning. It is about the knowledge of teaching and classroom management organisation (Shulman's study, as cited in Angeli & Valanides, 2015).

Angeli & Valanides (2015) further indicated that PK explains how learners learn, the sort of activities that encourage them to learn for self-assessment. In the Microsoft Math application, learners were actively involved in their own learning. Learner-centred, distance, active, collaboration, autonomous, situated and group work were the main teaching and learning methods and strategies. Auditory, visual and kinaesthetic learning styles were incorporated. The Microsoft Math was also used to motivate learners, including: to monitor; to assess; and to evaluate their progress. Immediate online feedback are provided to the learners. The learners self-assessed their progress online. PK supported this process.

TPACK (Model)

(Mishra and Koehler's study, as cited in Angeli & Valanides, 2015) presented the following intersections regarding smartphone technology:

- technological content knowledge (TCK),
- technology pedagogical knowledge (TPK),
- pedagogical content knowledge (PCK) and
- TPACK

Effective teaching and learning of algebra should transpire within a TPACK framework. Intersections of PCK, TPK and TCK should be included to ensure successful training.

PCK

This is the intersection and interaction of pedagogy and algebra CK where relevant knowledge, applicable to a specific content in mathematics should be taught, with various teaching and learning strategies, methods and styles (Angeli & Valanides, 2015). In this study, this included important knowledge of algebra teaching and learning content in the CAPS mathematics curriculum of Grade 10 learners. It was crucial to assess and evaluate learners' progress in algebra.

TPK

TPK Knowledge refers to an understanding of how algebra teaching and learning methods, strategies and styles change, when using smartphones technological devices (Angeli & Valanides, 2015). This considered the advantages and disadvantages of integrating mobile smartphones technologies in teaching and learning mathematics.

TCK

According to Angeli & Valanides (2015), in TCK, technology and content knowledge influenced each other. In this instance, Microsoft Math content in algebra was accessed through smartphones online.

The TPACK model, which was previously mentioned on pages 28 and 29, can be represented in a Venn diagram as depicted in Figure 3.1.

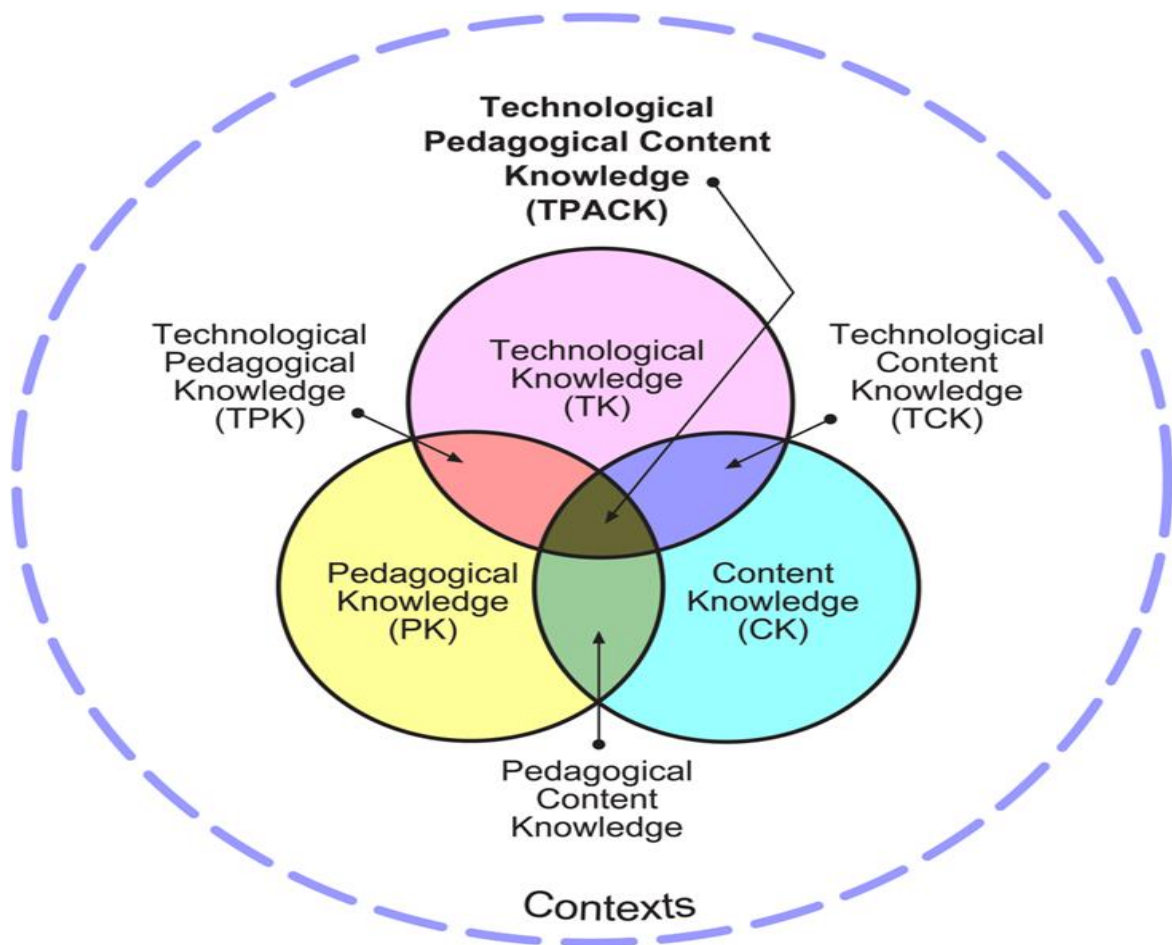


Figure 3.1: The TPACK model

Source: (Koehler & Mishra, 2006)

As aforementioned, this TPACK framework should be complemented by AT in integrating mobile smartphone technology in algebra teaching and learning to Grade 10 learners.

3.3 AT

AT uses cultural technological devices, such as smartphones used by Grade 10 learners in their daily activities. This AT is based on Vygotsky's work on the society's role and influence in teaching children (Angeli & Valanide, 2015). According to Woolfolk (2010), Vygotsky emphasises that social interaction, cultural devices and learners' activities, shape individual development and learning. In this study, smartphones are viewed as cultural devices, since they are popular amongst the learners in this digital age. The learners use these cultural devices for learning algebra.

The concept of the zone of proximal development, the area where a child can only understand a concept with the assistance (scaffolding) of an adult or a more able peer, are called a place where culture and cognition supplement one another (Woolfolk, 2010). In the study, learners used smartphones as cultural devices to develop cognitive algebra concepts anywhere and anytime in their society. The AT as a theoretical framework of integrating mobile smartphone technology in algebra teaching and learning was appropriate in this study mainly because it:

- was used for formal and informal algebra learning.
- was used inside and outside classroom situations.
- allowed monitoring learners' mathematics education in algebra, whilst they were involved in other activities.
- theorised algebra learning as a social and constructive process.
- allowed understanding, learning algebra as a personal, communal and situated activity, mediated by mobile smartphone technologies (Sampson *et al.*, 2013).

Sampson *et al.*, (2013) further, noted that according to the AT, activities indicate collective instrument systems, rules and labour division. The smartphones devices, rules and labour division, were used to achieve a common mathematical goal in algebra. Sampson *et al.*, (2013) also indicated that subjects, expected results,

community, devices, rules, division of labour and knowledge object are AT elements. In this study, the same AT elements were identified.

Subjects: Refers to each learner in the Grade 10 experimental group learning algebra, using the Microsoft Math application online and a smartphone.

Expected results: Integrating smartphone technology into algebra teaching and learning to the Grade 10 learners was expected to have a positive impact on the learners' achievement. The learners were also expected to develop critical mathematical thinking, acquire mathematical concepts they can use in real-life situations and to use mobile smartphones as educational devices in algebra.

Community: Refers to learners in the experimental group. The learners had smartphones to do algebra academic activities.

Devices: These included smartphones, which were used by learners to access the Microsoft Math website. .

Signs: Signs indicate mathematical language, mainly comprising a language of symbols, representing algebraic symbolic systems, such as the steps required to obtain the final answer.

Rules: The learners worked individually and in a group. The teacher formed an online group and invited each learner in the experimental group. To join the group, each member used an invitation key, generated online. The group and individual activities were based on collaboration and problem-solving learning. The learners competed in fun and friendly ways.

Division of labour: The teacher and learners partook in the learning and teaching of algebra. The learners were involved in their own learning, their main participation involved active participation in the activities, developed by Microsoft Math for individuals or groups. They learnt the algebra content. They monitored, assessed

and evaluated their work. The teacher acted as a designer of algebra learning activities, mediator, facilitator and guide for teaching algebra. The teacher also assessed and evaluated the learners' progress, during the Microsoft Math activities (Batista, Behar & Passerino, 2013).

Knowledge object: This included algebra sub-topics, such as: rational, irrational and algebraic products, factorisation, algebraic fractions, exponential equations and expressions, linear number patterns, linear, quadratic and simultaneous equations, word challenges, literal equations and linear inequalities.

3.4 Conclusion

The TPACK and AT were the conceptual and theoretical frameworks for conducting this study, the impact of integrating smartphone technology on Grade 10 learners' achievement in algebra. The connectivism, learner-centred, independence, group work, situated, cooperation and collaboration principles were also applied

CHAPTER 4: RESEARCH DESIGN

4.1 Introduction

The purpose of this chapter is to describe the research design. According to Cohen *et al.*, (2005), a research design is a plan used to answer the research questions. The research design chosen for the study, was considered the most appropriate concerning addressing the research problem.

4.2 Research methodology

The study was quantitative, using a quasi-experimental design. According to McMillan & Schumacher, (2010), a quantitative study make use of numbers, statistics, structures and controls. It was convenient to use a quasi-experimental design because there was no randomised sampling. In a quasi-experimental design, an intervention is administered to the experimental group. The control group must not get contact with the intervention (McMillan & Schumacher, 2010). This is to avoid diffusion of the intervention to the control group. Two intact township Grade 10 mathematics classes from A and B secondary schools participated in the study. Both schools are in the GDE Province. Each class had its own mathematics teacher. The class from the A secondary school was experimental and the class from the B secondary school was the control.

Population

The target population were learners between the ages of 15 and 17 years, studying Grade 10 algebra in township schools in the GDE Province.

Sample size

A sample of two Grade 10 classes from the target population participated in the study. These classes were from A and B secondary schools in the GDE Province. Each of the classes from the two secondary schools had about 30 learners and its own mathematics teacher. One class from secondary school B was a control group and the other class from secondary school A was an experimental group.

Participation selection

For convenience, two established Grade 10 classes from A and B secondary schools were selected. Each class had about 30 learners. These classes had their own mathematics teachers.

Instruments

Pre-test and post- test

The control and experimental classes wrote a pre-test on hard copies to assess their academic achievement prior to an intervention programme administered to the experimental group. After the intervention programme to the experimental group by the researcher, both groups wrote a post-test. The control group was being taught algebra by its mathematics teacher. The purpose of the post-test was to establish the impact of integrating smartphone technology on Grade 10 learners' achievement in algebra. Each test took an hour for completion. These tests were written after school hours, under examination conditions. The tests covered the Grade 10 sub-topics on algebra in the (ATP) for the first term. The sub-topics were:

- Rational, irrational and algebraic products,
- Factorisation,
- Algebraic fractions,

- Exponential equations and expressions,
- Linear number patterns,
- Linear, quadratic and simultaneous equations,
- Word challenges and
- Literal equations and linear inequalities.

Online exercises

Learners in the experimental group also did algebra exercises online on the Microsoft Math website, <https://www.math.microsoft.com> anytime and anywhere. These exercises covered the algebra content in the ATP for the first term. The online exercises were divided into levels of difficulty. When a set of online quizzes were mastered, the learner was progressed to the next level of difficulty. There were ten levels in each sub-topic. Examples of the levels for the sub-topic: Rational, irrational and algebraic products are provided in Appendix F. These exercises were marked online immediately after an answer was submitted online. When learners submitted correct answers, they were awarded marks online. This encouraged them to perform online activities independently, using their smartphones, anytime and anywhere (Microsoft Maths, 2015).

Data collection

For convenience, two established Grade 10 classes were involved in the study. It was easy for the researcher to work with these classes because they were conveniently available at A and B Secondary Township schools in the GDE Province. Each class had 30 learners and its own mathematics teacher. The participants wrote a pre-test and a post-test after school hours to assess their academic achievement before and after an intervention programme was provided to the experimental group. The time allocated for each test, was one hour. The tests were conducted under examination conditions. The invigilator was the research administrator, marking the tests and recording the marks obtained by each learner. For the online exercises, the researcher frequently logged onto the Microsoft Math

website: (<https://math.microsoft.com>) to observe the marks obtained by each learner in the experimental group online for performing algebra exercises, and to observe the learners who were actively involved with online exercises. Each learner in the experimental group's marks were recorded.

Intervention

Microsoft (Mobile) Math was used for teaching and learning Grade 10 algebra. It was a free online application for Grade 10 mathematics support service, providing CAPS aligned activities (Microsoft Math, 2015). Learners performed exercises, watched videos, read theory and learnt from examples on algebra. They used the service anytime and anywhere. The learners accessed the Microsoft Math website through their smartphones. The application service was used twice a week after school hours. Each session took an hour. The intervention programme was done for six weeks. They also used the Microsoft Math application during their free time, anytime and anywhere.

The researcher introduced the sub-topics. Then, Grade 10 learners in the experimental group used their smartphones to perform exercises. They were free to watch videos, read theory, hints, and learn from examples before or after they conducted the activities. They formed a study group online to see how each group member in the experimental group performed, through a friendly and fun competition. Each group member received marks after completing the exercises and doing them correct. The exercises were immediately marked online. There were added incentives for those in the experimental group because they gained marks whenever they answered activities correctly.

4.3 Data analysis

For the pre-test and post-test, histograms were extracted to indicate the achievement distribution of the marks of the learners in the control and experimental groups before and after the intervention, using a Microsoft excel spreadsheet. The

histograms were used to describe the skewness of the achievement distribution of the marks the learners received in the pre-test and post-test. The marks that the learners obtained in the tests were grouped into five class-intervals, using frequency distribution tables. A paired samples dependent t- test was also used to infer data for the pre- and post-tests of both the control and experimental groups in a useful and informative way.

For the online exercises conducted by the experimental group, a table was used. The table indicated the expected marks and actual marks each learner obtained in the algebra sub-topics on the Microsoft website. The $\frac{\text{actual mark}}{\text{expected mark}}$ of each learner in the experimental group was then converted to a percentage.

4.4 Validity and reliability

According to Fraenkel & Wallen (2009), validity refers to the appropriateness, meaningfulness, correctness, and usefulness of a specific conclusion based on the data collected. Validity is essential to consideration when choosing an instrument to use. Fraenkel & Wallen (2009) further indicate that reliability refers to the reliability are described below concerning the pre-test and post-test, used in the study.

Validity

To ensure validity, the tests and the memorandum were pre-moderated by the Heads of Department (HOD) of the schools where the research was conducted. The same memorandum was used, since the post-test was the same as the pre-test. . Each learner's answers were post- moderated by his/her HOD. Certain questions in the tests were once used by experienced researchers who conducted similar researches, involving the impact of integrating smartphone technology in Grade 10 learners' achievement in algebra.

Reliability

The algebra test was designed in such a way that if Grade 10 mathematics learners who are doing CAPS write it, the results would be consistent. The tests were written under examination conditions. The research administrator was the invigilator.

4.5 Ethical considerations

The study dealt with human beings. It was therefore necessary to consider the ethical and legal responsibilities of a conducting research (McMillan & Schumacher, 2010). Below are certain research ethics and legal considerations applied in the study.

Data storage

The data were stored and kept as hard and soft copies for future reference on the research study.

Findings or results of the study

The schools were provided with bounded hardy copies and compact discs of the completed research for their libraries. On completion of the study, the researcher provided a short speech concerning useful and interesting information obtained through the study. The participants were invited to the information session at the research schools after hours.

Informed permission, consent and assent

Correspondence was issued to obtain permission to conduct the study, from the principals of the schools where the proposed study was conducted, the GDE, consent from the parents/guardians of the participants and assent from the participants. The College of Education of UNISA had to issue the research ethics clearance correspondence prior to collecting data from the research sites.

Confidentiality

The schools' and the participants' names were kept completely confidential at all times in the academic recordings during the study. Their privacy was maintained in all published and written data, resulting from the study. Numbers were used to code identity names in this study. The first two letters of the alphabet (A and B) were used to code the participating schools.

Participation

Participation in this study was voluntary. A participant was free to participate or to withdraw from participation at any time. The withdrawal or refusal of participants did not affect their relationship with the school or the researcher. The parent/guardian could agree to allow their children to participate in this study. They could change later without any penalty. The participant could agree or disagree to be part of the study. Those who did not agree to participate were excluded from this study and there was no penalty.

Remuneration

No remuneration was received for participating in this study. Each participant in the experimental group received individual marks for answering algebra activities online correctly. This was a way of encouraging the participants to do Microsoft Math

independently, using their smartphones anytime and anywhere, indicating added incentives for those in the experimental group.

Queries

All the individuals involved in this study, with questions about their rights or any dissatisfaction with any part of the study, were free to contact anonymously the GDE on +27113550909 or the research administrator on +27117945810.

Conflict of interest

The experimental group was at the researcher administrator's work place. The researcher refrained from letting unduly opinions and perceptions affect the study. Instead, the data guided the study.

4.6 Conclusion

The research design helped in drawing valid conclusions concerning the study. This chapter describes the research methodology, data analysis, validity, reliability, and ethical considerations.

CHAPTER 5: DATA ANALYSIS, FINDINGS AND DISCUSSION

5.1 Introduction

This chapter focuses on discussing the data analysis and the data findings. Systematically the following headings were arrived at; organising and summarising data; findings and discussion. The findings are summarised during the conclusion of the chapter.

5.2 Organising and summarising data

Descriptive and inferential statistics were used to organise, infer and summarise the learners' marks, obtained in the pre-test, post-test and online exercises. These tests were conducted for control and experimental groups. The experimental group did the online exercises.

The control group

The following presents the pre-test and post-test data for the control group.

Pre-test data





The organised and summarised data for the pre-test is represented in Tables 5.1 and 5.2.

**Table 5.1: Algebra pre-test marks for the control group in an ascending order
(n = 30)**

8%	8%	10%	12%	12%	14%	14%	14%	16%	16%
16%	18%	18%	22%	22%	24%	24%	24%	26%	32%
36%	38%	38%	42%	46%	46%	50%	54%	56%	70%

Table 5.1 indicates that the mean for algebra marks was about 27% and the median was 23%. The range of the marks was 62, ranging from 8% to 70%. The mean and the median, measuring central tendency were low and the spread measure range was large.

Table 5.2: Algebra pre-test marks grouped frequency distribution table for control group (n = 30)

Class-interval as percentages	Tally	Frequency
0-19		13
20-39		10
40-59		6
60-79		1
80-99		0

Data used in Table 5.2, demonstrates the modal class 0-19%. Using the frequency column, 23 from 30 learners got less than 40% in the pre-test.

Post-test data

The organised and summarised data for the post-test is represented in Tables 5.3 and 5.4.

**Table 5.3: Algebra post-test marks for the control group in an ascending order
(n = 30)**

5%	6%	8%	8%	12%	14%	16%	16%	18%	20%
22%	22%	24%	26%	26%	26%	28%	28%	32%	40%
40%	42%	46%	46%	48%	50%	52%	54%	60%	68%

Table 5.3 indicates that for algebra post-test marks, the mean as about 30%, whilst the median was 26%. The range of the marks was 63, fluctuating from 5% to 68%.

Table 5.4: Algebra post-test marks grouped frequency distribution table for the control group (n = 30)

Class-interval as percentages	Tally	Frequency
0-19		9
20-39		10
40-59		9
60-79		2
80-99		0

Table 5.4 indicates the summarised data of the model class for the post-test as 20-39%. The sum of the frequencies of the classes 0-19 and 20-39 was 19, indicating more than 50% of the learners in the control class.

Table 5.5: A paired samples dependent pre-test and post-test marks for the control group.

Name of learner	Post-test (%)	Pre-test (%)	Difference
1	22	16	6
2	14	24	-10
3	28	22	6
4	26	16	10
5	54	54	0
6	6	8	-2
7	26	22	4
8	8	12	-4
9	26	14	12
10	24	24	0
11	12	12	0
12	52	38	14
13	46	42	4
14	60	24	36
15	42	36	6
16	28	14	14
17	22	14	8
18	8	8	0
19	32	50	-18
20	46	46	0
21	16	26	-10
22	40	32	8
23	16	10	6
24	20	16	4
25	40	56	-16
26	68	70	-2
27	48	38	10
28	5	18	-13
29	18	18	0
30	50	46	4

Experimental group

The pre-test, online exercises, post-test and a paired samples dependent data for the experimental group are below.

Pre-test data

Table 5.6: Algebra pre-test marks for the experimental group in an ascending order (n=30)

4%	8%	8%	12%	14%	15%	16%	16%	16%	18%
18%	18%	20%	20%	22%	24%	28%	30%	30%	32%
34%	38%	42%	44%	48%	50%	52%	54%	60%	72%

Table 5.6 indicates the mean of algebra marks at an average of about 29%; the median was 26% and the range was 68%.

Table 5.7: Algebra pre-test grouped frequency distribution table for the experimental group (n= 30)

Class-interval as a percentage	Tally	Frequency
0-19		12
20-39		10
40-59		6
60-79		2
80-99		0

Table 5.7 indicates that the algebra pre-test modal class for the experimental group was 0-19 - the same as the control group modal class. The frequency column in Table 5.7 also indicates that 22 from 30 learners obtained less than 40%.

Online exercises

Each learner in the experimental group was expected to gain 3 600 marks after performing online algebra exercises. They performed the exercises and submitted the answers online. The solutions were marked immediately online. Feedback was also provided. The algebraic topics were divided into sub-topics:

- Rational, irrational and algebraic products.
- Factorisation
- Algebraic fractions.
- Exponential equations and expressions
- Linear number patterns.
- Linear, quadratic and simultaneous equations
- Word challenges.
- Literal equations and inequalities

Eight sub-topics were divided into ten levels. A learner was awarded 450 marks for answering all the questions in each sub-topic correctly. Table 5.8 indicates the marks awarded to each learner in the experimental group for the online exercises.

Table 5.8: Online marks and percentages for learners in the experimental group (n = 30)

Name of learner	Actual marks gained	Percentages
1	750	21
2	2 700	75
3	1 305	36
4	1 605	45
5	2 575	72
6	720	20
7	40	1
8	2 585	72
9	500	14
10	2 505	70
11	3 580	99
12	2 655	74
13	2 000	55
14	280	8
15	2 295	64
16	2 385	66
17	855	24
18	40	1
19	220	6
20	60	2
21	30	1
22	2 400	67
23	1 730	48
24	2 450	68
25	1 575	44
26	80	2
27	3 205	89
28	2 355	65
29	60	2
30	3505	97

Table 5.8: indicates that sixteen learners were awarded 40% and above. More than 50% of the learners in the experimental group, were awarded 40% and above.

Table 5.9: Algebra post-test marks for the experimental group in an ascending order (n = 30)

10%	22%	22%	24%	24%	26%	30%	30%	32%	34%
34%	38%	40%	42%	48%	50%	54%	56%	60%	60%
64%	66%	68%	68%	70%	72%	74%	74%	80%	96%

Table 5.9 indicates that the mean of algebra marks was 48, 9% and the median was 49%. There was not much difference between the mean and the median. The range of the marks was 86; the range was high because of outliers. Sixty per cent of the learners in the experimental group were awarded 40% and above.

Table 5.10: Algebra post-test marks for the experimental group's grouped frequency distribution table (n = 30)

Class-interval as percentages	Tally	Frequency
0-19		1
20-39		11
40-59		6
60-79		10
80-99		2

Although the modal class from Table 5.10 indicates a class with low marks, the sum of the frequencies of the classes above it, was greater than the frequencies of the modal class and the class below it.

Table 5.11: a paired samples dependent pre and post-tests marks for the experimental group.

Names of learners	Post-test (%)	Pre-test (%)	Difference
1	34	18	16
2	72	52	20
3	30	38	-8
4	48	20	28
5	64	54	10
6	50	8	42
7	22	8	15
8	74	60	14
9	24	4	20
10	60	42	18
11	96	72	24
12	68	28	40
13	42	24	18
14	34	20	14
15	74	15	59
16	70	32	38
17	38	18	20
18	22	16	6
19	30	12	18
20	26	16	10
21	10	14	-4
22	56	48	8
23	66	44	22
24	24	30	-6
25	60	22	38
26	40	18	22
27	68	50	18
28	54	34	20
29	32	16	16
30	80	30	50

5.3 Findings and discussion

The findings from the pre-test and post-test marks for control and experimental groups are discussed.

Control group histograms

The pre- and post- tests histograms for the control group are shown in Figures 5.1 and 5.2, respectively.

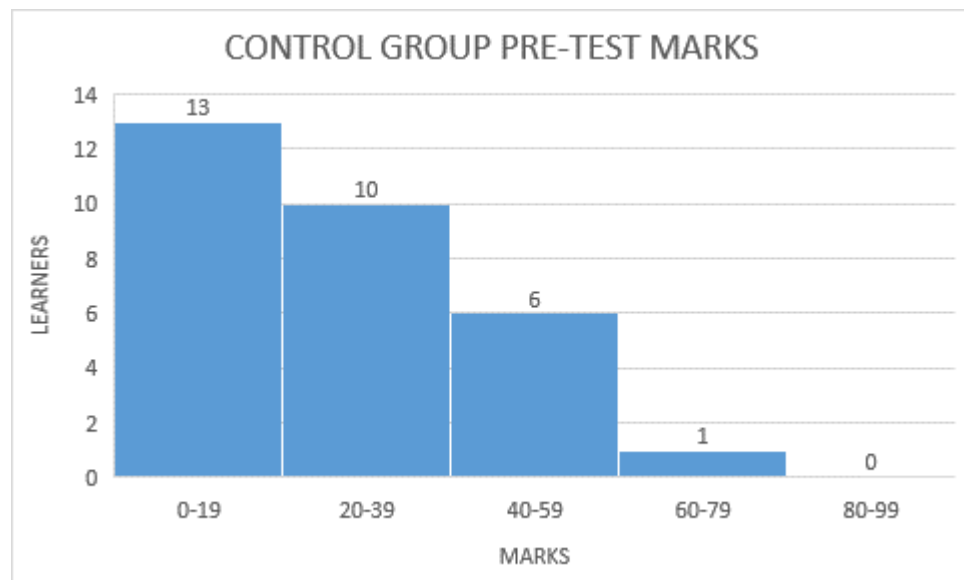


Figure 5.1: The control group's pre-test marks (n = 30)

Figure 5.1 indicates that 23 learners in the control group obtained scores of 39% and below for the pre-test. Only six learners obtained scores of 40-59%, whilst one learner obtained a score of 60% or more. The data was positively skewed or skewed to the right (Phillips, 2014). Most marks that the learners in the control group got in the pre-test, were to the left side of data distribution, with no remarkably high marks on the right. Table 5.1 indicates the mean at about 28% and the median at 23%. The mean was greater than the median. This also implies that most learners in the

control group got low marks in the pre-test. The modal class in Table 5.2 was 0-19, supporting the observation regarding the deficient performance of the control group learners in the pre-test.

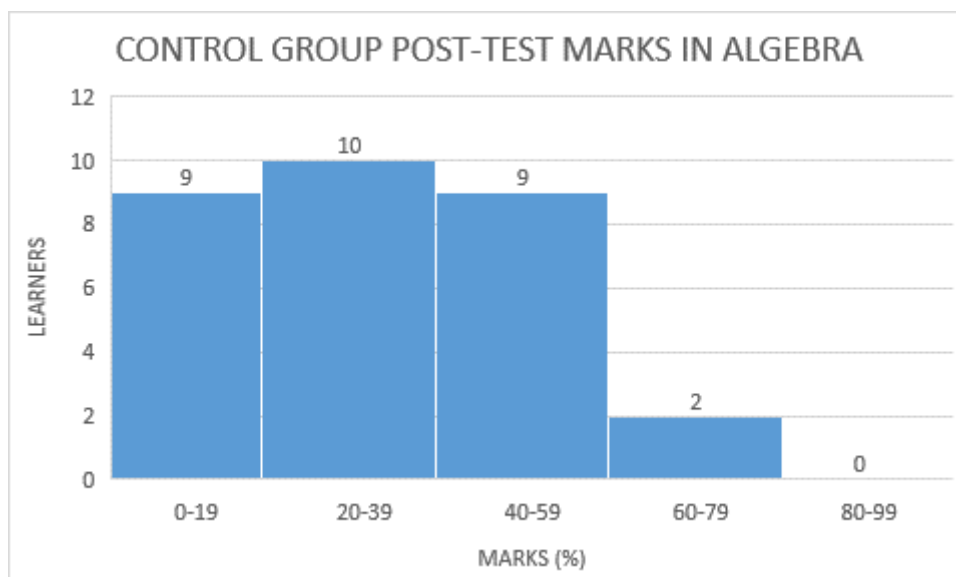


Figure 5.2: Control group's post-test marks (n= 30)

Figure 5.2 indicates that the number of learners in the control group for the post-test who received 39% and below, decreased from 23 learners to 19 learners, compared to the pre-test (Figure 5.1). The data was still positively skewed. Table 4.3 signifies that the mean was still greater than the median. The mean of data improved from 28% in the pre-test to 30% in the post-test.

The median increased from 23% in the pre-test to 26% in the post-test. The modal class in Table 5.4 was 20-39. There was a slight improvement in the control learners' performance in the post-test, compared to the pre-test, although most learners under-performed. The reason for the slight improvement in performance could be due to the maturity of certain learners. In addition, post-test was also written at the end of the first term when the learners were revising for the algebra term-end test.

Experimental group histograms

Figures 5.3 and 5.4 indicate the pre-test and post-test histograms for the experimental group, respectively.

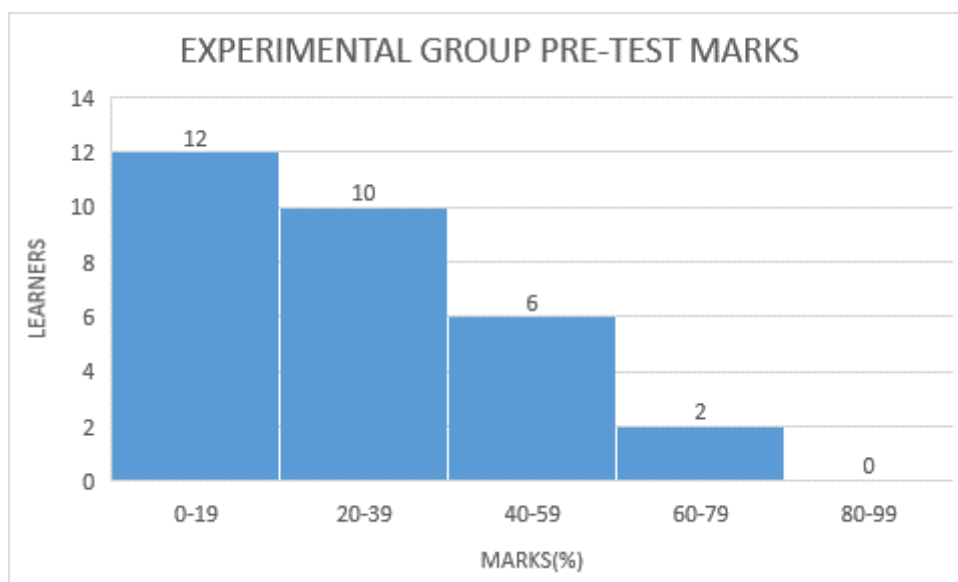


Figure 5.3: The experimental group's pre-test marks (n= 30)

In the algebra pre-test, 22 learners from the experimental group got 39% and below and eight learners got 40% and above. Figure 5.3 signifies this information. Most learners got low marks. Data distribution for the experimental group was the same as data distribution for the control group in pre-test. It was also positively skewed or skewed to the right. The mean was 30% and the median was 26%. Table 5.6 indicates that the mean was greater than the median. This also supports the skewness of data distribution to the right. The modal class from Table 5.7 was 0-19. Most learners in the experimental group received low marks in the pre-test. They were at the same low performance level with the control group.

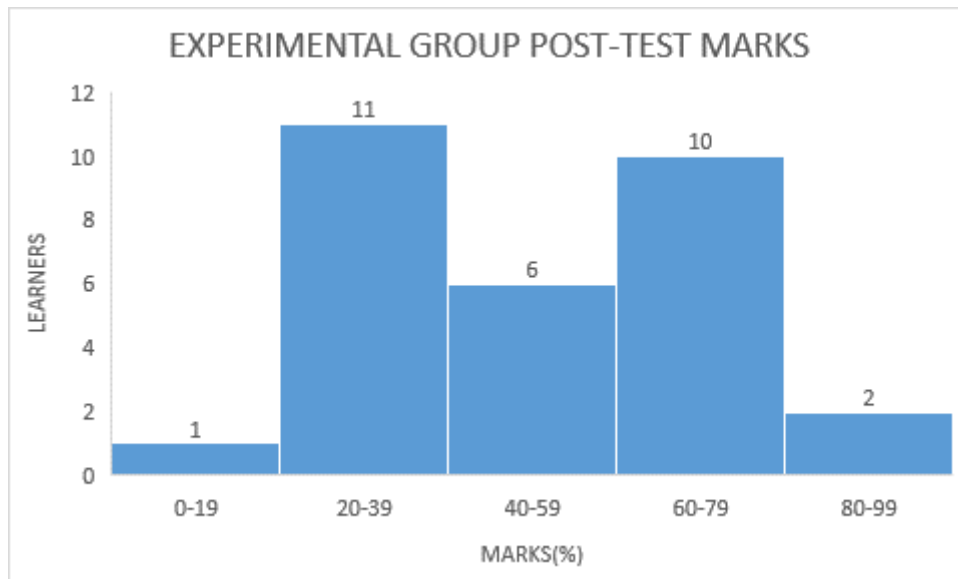


Figure 5.4: Experimental group's post-test marks (n=30)

After the intervention programme administered to the experimental group, there was an improvement in the performance of certain learners in the post-test. Figure 5.4 indicates that 18 learners obtained 40% and above and 12 learners got 39% and below in the post-test; in the pre-test, eight learners received 40% and above and 22 learners received 39% and below. The distribution of data was neither skewed to the right nor skewed to the left. It was also not normally distributed. The mean was slightly less than the median indicated in Table 5.8.

Effect of online exercises on experimental group

Table 5.12: Algebra online marks and post-test marks, as percentages for the experimental group

Name of learner	Online marks as percentages	Post-test marks as percentages
1	21	34
2	75	72
3	36	30
4	45	48
5	72	64
6	20	50
7	1	22
8	72	74
9	14	24
10	70	60
11	99	96
12	74	68
13	55	42
14	8	34
15	64	74
16	66	70
17	24	38
18	1	22
19	6	30
20	2	28
21	1	10
22	67	56
23	48	66

Name of learner	Online marks as percentages	Post-test marks as percentages
24	68	58
25	44	60
26	20	40
27	89	68
28	65	54
29	2	32
30	97	80

From Table 5.12, the learners who were active on the online exercises also performed well in the post-test. Since the learners in the experimental group conducted most online exercises after school hours, independent learners performed well in the post-test.

A paired samples dependent t-test.

A paired samples dependent t-test was also used to determine whether there was no significant mean difference between the post-test and the pre-test marks of the groups. In this research study, the same learners' marks were recorded before and after an intervention was administered to the experimental group.

Null Hypothesis (H_0): There was no significant mean difference between the post-test and the pre-test marks.

Alternate Hypothesis (H_A): There was a significant mean difference between the post-test and pre-test marks.

Control group

	Pre-test	Post-test
Mean	27,53333333	30,1
Standard Deviation	16,40591427	17,2133669
Variance	269,154023	296,3
Observations	30	30
Degrees of freedom	29	29
Hypothesized mean	0	

The mean of the difference between the post-test and the pre-test marks (\bar{X}_d) = 2,566666667.

The standard deviation of the difference between the post-test and the pre-test marks (S_d)=10, 41114566.

The variance of the difference between the post-test and the pre-test marks = 108,391954.

$$t_{calculated} = \frac{\bar{X}_d - 0}{\frac{S_d}{\sqrt{n}}} = \frac{2,566666667}{\frac{10,41114566}{\sqrt{30}}} = 1,350304065.$$

$t_{critical}$ = 2,045 at alpha equal to 0, 05.

$$t_{calculated} < t_{critical}$$

We fail to reject the null hypothesis. This implies that there was no significant improvement in the control group's achievement in algebra.

Experimental group

	Pre-test	Post-test
Mean	28,76666667	48.93333333
Standard Deviation	17.22004312	21,50690881
Variance	269,154023	462,5471264
Observations	30	30
Degrees of freedom	29	29
Hypothesized mean	0	

The mean of the difference between the post-test and the pre-test marks (\bar{X}_d) = 20, 2.

The standard deviation of the difference between the post-test and the pre-test marks (S_d) = 15, 2686271.

The variance of the difference between the post-test and the pre-test marks = 233, 1310345.

$$t_{calculated} = \frac{\bar{X}_{d-0}}{\frac{S_d}{\sqrt{n}}} = \frac{20,2}{\frac{15,2686271}{\sqrt{30}}} = 7,246228223.$$

$t_{critical}$ = 2,045 at alpha equal to 0, 05.

$t_{calculated} > t_{critical}$.

We reject the null hypothesis. This means, there was a significant difference between the pre-test and post-test marks. Therefore, the integration of smartphones in the teaching and learning of algebra had a positive impact on the experimental group's achievements.

5.4 Summary

During the intervention programme, learners in the experimental group were actively involved in their own learning, through the following learning methods:

- collaborative,
- activity-based,
- problem-based,
- work-based,
- independent,
- ubiquitous,
- distance,
- cooperative and

- learner-centred.

They learnt algebra, using their own smartphones, accessing the website: <https://math.microsoft.com>. The role of the teacher was to facilitate, guide and monitor the learners. Most learners learnt algebra anytime and anywhere, after school hours. They independently performed online exercises on the Microsoft Math website. This was supported by the marks they were awarded. The teacher would log onto the website immediately after the periods assigned to do the intervention programme weekly at school (after hours) prior to the intervention programme, occurring the following week.

Certain learners' performances (in the experimental group) improved after smartphone technology was integrated in algebra teaching and learning. The experimental group conducted online exercises, motivating certain learners to work independently anywhere and anytime. Certain experimental independent group learners, who actively participated in the online exercises, post-test performances improved.

CHAPTER 6: CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

6.1 Introduction

Chapter 5 analysed, organised, summarised, interpreted, represented and inferred data obtained. Chapter 6 focuses on conclusions, recommendations and study limitations.

6.2 Conclusion

It emerged from the study, that it is possible to improve Grade 10 learners' achievement in algebra, by integrating smartphone technology. Damick (2015) supports the study view, indicating that smartphone technology is essential for algebra teaching and learning, since it influences the way algebra is taught and enhances teaching and learning.

In the study conclusion, the main aspects are summarised, concerning the following aspects, derived from the research sub-questions:

- teaching and learning methods,
- learning styles,
- appropriateness of smartphone technology,
- usefulness of smartphone technology to provide supportive materials,
- effectiveness of smartphone technology in providing support,
- the impact on independence of learners when smartphones are integrated and
- challenges of integrating smartphones.

6.2.1 Effectiveness of smartphone technology in providing support

Integrating smartphone technology in algebra teaching and learning provides an improved practice in learner engagement (Lu, 2012). During the intervention programme at the study school, the learners were involved in their own learning. The following essential teaching strategies for effective teaching and learning of algebra to certain learners were provided for in the study.

- activity-based,
- work-based,
- problem-based,
- opinion-based,
- collaborative learning,
- independent learning,
- life-long learning,
- distance learning,
- ubiquitous and
- learner-centred.

6.2.2 Teaching and learning methods, and learning styles

During the study, the teacher was the facilitator of algebra content learning and the facilitator of digital smartphone technology learning. The learners were involved in their own learning continuously, using their smartphones as ‘textbooks’. Learning algebra was not restricted to school hours and learner-centred education was used. Various teaching and learning methods were incorporated with integrating smartphones for algebra teaching and learning. Learners with various learning styles were catered for, through integrating smartphone technology.

6.2.3 Appropriateness of smartphone technology

According to (Fetaii's study, as cited in Lu, 2012), it is believed that smartphone technology will become the most popular and convenient teaching and learning method. This is supported by subjects of the study (learners), owning smartphones, used for accessing algebra information online. The study school lacks efficient ICT devices, such as laptops, personal computers and tablets, for each learner. ICT integration in mathematics education is being encouraged in this technology era. It may be appropriate for the school to allow the learners to bring their own mobile technological devices for integration into teaching and learning mathematics content, such as algebra. Smartphones have functions and features, found in other technological devices, such as laptops, personal computers and tablets.

Laptops, personal computers and tablets are the most common ICT devices used in schools. These devices must be purchased and maintained. Most subjects (learners) in the study could buy and maintain their own smartphones. This implies that the Department of Education, schools and educational non-governmental organisations, may not spend copious funds on purchasing and maintaining the learners' technological devices if smartphones are integrated for teaching and learning purposes.

6.2.4 Usefulness of smartphone technology to provide support material

Learners use smartphones as cultural devices in the society. There are several benefits in using smartphones as LTSM in teaching and learning mathematics content, such as algebra. It is unlikely that smartphone technology will be discontinued. Teachers who are phobic about technology should be encouraged to change their opinion concerning using smartphones, teaching mathematics content. Smartphones should be integrated in the teaching and learning of mathematics content for the benefit of digital native learners. Polly (2015) identified technology as an integral function in teaching and learning mathematics in the 21st century society.

Gunter & Gunter (2015) also indicated that teaching should provide teachers with integrated strategies and ideas for reaching the digital generation. The school policy that does not allow learners to bring smartphones for education purposes to the study school, should be revisited and revised. In the study, smartphones were used as educational technological devices. The result indicated a positive impact on certain learners' achievement in algebra. It can be concluded that smartphones are useful LTSM based devices, influencing certain learners' achievements.

An identified purpose of mathematics education is to prepare learners for life in the real world where smartphones are used anywhere and anytime in the community and the job market. The 21st century employers aspire employees who can use current, new and emerging ICT devices in the work place. The employers and employees must be able to adapt to a global, fast-changing technology. Learners represent future employers and employees.

6.2.5 Impact on independence of learners, using smartphones

Certain learners practised algebra anywhere and anytime outside the school environment. This promoted independent learning amongst them. Those independent learners indicated a positive impact on their algebra achievements.

Certain SA students under-perform at tertiary institutions, as they lack independent learning. Integrating smartphone technology may empower them to independence. A technologically fast-changing world is overwhelmed by political, social and economic hardships and challenges. Independent adults and good decision-makers are needed in the world, as learners are the future's adults. Teachers have a significant influence on learners by developing their abilities.

6.2.6 Challenges of integrating smartphone technology

Although, smartphone technology was ideal and relevant during the study, it was not always reliable. Certain learners encountered challenges beyond the teacher's control.

The research study was funded by UNISA. Therefore, the research administrator bought data for the learners to access the relevant website:

<https://.math.microsoft.com>. Certain learners indicated that the data was not enough for the online process, learning algebra. Unfortunately, some of the learners were not willing to buy their own extra data since they are used to free services offered by the government. The government supplied most learners' educational needs, since the study school is a non-paying school fees. Although it is a non-paying school fees, some of the parents and guardians have good jobs.

The other challenge was of learners who used small smartphone handsets, which had small screens. The screens did not display all the devised algebra information. This hindered the learners' progress. In addition, certain learners arrived at the school with smartphones, indicating low battery capacities. They could not load electrical energy because of resulting load-shedding interferences at their home environments. Those learners would then load their smartphones during the time allocated for algebra exercises. As a result, they spent less time performing algebra exercises. In certain incidences, the learners wanted to charge their smartphones at the school whilst there was no power, due to unforeseen reasons. Those learners were frustrated, concluding that they refrained from being involved in the online algebra exercises.

Sometimes the mobile cellular networks, such as Cell C, MTN, Vodacom and Telkom were not available at the research study school. This resulted in time-consuming logging onto the Microsoft Math website. On certain days, learners failed to access the website this demotivated them. Certain learners logged onto other websites, non-related to learning algebra. So time allocated for learning algebra

using smartphones as technological devices, was not fully utilised. Towards the end of the study, a learner's smartphone was stolen outside the school premises. The learner was not further involved in exercising Microsoft Math. This hindered the learner's progress. Despite the aforementioned challenges, a positive impact was indicated on certain learners' achievement in algebra.

6.3 Recommendations

Although smartphone technology can improve learners' achievements when properly integrated, it cannot replace the mathematics teacher. There is need for further research, on the impact of integrating smartphone technology on Grade 10 learners' achievement in algebra in rural, town and townships schools, to validate the research findings. Humanity immersed in technology, but most practising mathematics teachers were not trained or skilled to integrate smartphone technology in teaching and learning mathematics content. Certain teachers were born before technology intervention. Therefore, there may be need for in servicing these teachers.

6.4 Limitations

The study participants were restricted to two established classes from different township schools. Each class had its own mathematics teacher. The sample did not represent the population of all Grade 10 algebra learners in the Gauteng Province. It was beyond the control of the research to alter the times of conducting the study. It was conducted after school hours when most learners indicated tiredness and they were anxious to go home and rest or be involved in other activities. This might have affected their test achievements.

Concerning the online exercises, it was difficult to establish whether the marks earned by the learners resulted from the algebra exercises only, since the Microsoft Math website includes all Grade 10 mathematics topics. Some of the learners may

have gained certain marks from exercises on alternative topics. The aforementioned factors might have distorted the validity of the study results and findings.

REFERENCE LIST

Angeli, C. & Valanides, N. (2015). Technological Pedagogical Content Knowledge: Exploring, Developing and Assessing TPCK. New York. SpringerYork. Springer Science + Business Media.

Batista, S.C.F. & Barcelos, G. T. (2014). Consideration on the use of mobile phones in Educational Context. *International Journal on New Trends in Education and their Implications*, 5(1).

Batista, S. C. F., Behar, P. A., & Passerino, L.M.(2013).Activity Theory and M-learning in the teaching of Calculus .In D. G. Sampson, P.I. D. Ifethaler & J. M. Spector (Eds.). *Ubiquitous and Mobile Learning in the Digital Age*. New York.Springer Science+ Business Media.

Charamba, C. (2015). Cellphones in schools, the grand debate. *Zimbabwe Herald*: [http:// www.herald.co.zw/ cellphones-in-schools—the grand debate/](http://www.herald.co.zw/cellphones-in-schools—the%20grand%20debate/) (Accessed March 2015).

Chen, Y. (2015). The international review of research in Open and Distributed Learning. *Linking learning styles and learning on mobile*. Vol 16, No 2. (2015). Athabasea University.www.irrodl.org/inex.php/irrodl/article/view/2038/3271. (Accessed May 2016).

Cohen, L., Manion, L. & Morrison, K. (2005) Research Methods in Education. (5th Ed.) New York: RoutledgeFalmer.

Dennis, P. (2015). *Three ways mobile technology is transforming learning spaces*. The journal Aug/Sep 2015, Vol 42 Issue 5, p 10-15.

Fraenkel, J.R. & Wallen, N.E. (2009). How to design and evaluate research in education. (7th Ed.). New York, NY: McGraw-Hill Higher Education.

Gourova, E., Asenova, A. & Dulev, P. (2013). Integrated Platform for Mobile Learning. In D. G. Sampson, P.I. D. Ifethaler & J. M. Spector (Eds.). *Ubiquitous and Mobile Learning in the Digital Age*. New York. Springer Science+ Business Media.

Gunter, G.A. & Gunter, R.E. (2015). Teachers Discovering Computers. Integrating Technology in a Changing World. Boston.(8th Ed.) Cengage Learning.

Honikman, M. (2016). A private tutor for each learner. Paper Video. *The teacher*. April 2016.

Huang, R., Hsiao, C., Tang, T. & Lien, T. (2014). Exploring the Moderating Role of Perceived Flexibility Advantages in Mobile Learning Continuance Intention (MLCI). *Journal of the International Review of Research in Open and Distance Learning*, Taiwan, 15(3), 141-156.

Koehler, M.J., & Mishra, P. (2006).Technological pedagogical content knowledge: A framework for integrating technology in teacher knowledge. *Teachers' college record*. 108(6), 1017-1054.

Lu, J. (2012). Learning with Mobile Technologies, Handheld Devices, and Smart Phones. Hershey. Information Reference.

Macmillan Teacher Campus, (2014). Grade 12 Teacher Training Material, *Sci-Bono Discovery Centre*. Northlands. Gauteng Department of Education.

Mcmillan, J.H. & Schumacher, S. (2010). Research in Education. (7th Ed.). Boston.

Meek, C. (2015) Onslow County Schools Excellence in Education. Jacksonville. www.onslowcounty.schoolinsites.com. (Accessed June 2016).

Meyer, B., Haywood, N., Sachdev, D. & Faraday, S. (2012). What is learning and what are the benefits for students? Department for Children, Schools and Families Research Report 051. London.

Microsoft Math, (2015) Excel at High School with Microsoft Math. Copyright.

Mzekandaba, S. (2013). Nokia unveils mobile maths service. Retrieved from <http://www.itwebafrica.com/--southafrica-nokia-unveils-m>. (Accessed June 2015).

Nelson Mandela Metropolitan University, (2013). Our South African youth must study maths and science in order for us to be a winning nation: Govan Mbeki Mathematics Development Unit, Port Elizabeth. Retrieved from mbeki-maths-dev.nmmu.ac.za. (Accessed June 2015).

Online Learning Consortium, (2015). The Special Issue to explore the realm of K-12 Online Learning. *The Official Journal of OLC*. 19 (5)

Ormiston, M. (Undated). How to use cell phones cellular phones as learning tools. Available from <http://www.teachhub.com/retrieved> April 2015.

Phillips, M.D.,(2014).Mathematics textbook Grade 10 NCAPS. Sanlamhof, Allcopy Publishers.

Polly, D. (2015). Cases on Technology Integration in Mathematics Education. Charlotte. Information Science Reference.

Prensky, M. (2001). Digital Natives, Digital Immigrants, *On the Horizon MVB University Press*, 9(5), 1-6.

Rastogi, S. (2015). Educational technology for effective teaching. Institute of Distance Education. Kwaluseni. University of Swaziland.

Rikhye, R., Cook, S. & Berge, L. (2009). Digital Native vs. Digital Immigrants: Myth or Reality. *International Journal of Instructional Technology & Distance Learning*, 6(2), 3.

Roberts, N. & Vanska, R. (2011). Challenging assumptions: Mobile Learning for Mathematics Project in South Africa. *Distance Education*, 32 (2), 243-255. Cape Town. Routledge Taylor& Francis Group.

Roberts, N. (2015). From challenging assumptions to measuring effect: Researching the Nokia Mobile Mathematics Service in South Africa. *South African Journal of Education: 35(2), 1-13*

Sampson, D.G., Ifentthaler, P.I.D. & Spector, J.M. (2012). Ubiquitous and Mobile Learning in the Digital Age. New York. Springer Science.

Teacher Reporter. (2016).Your guide to education. *Helping your child to use the internet wisely*.

Traxler, J. (2010). Will students' devices deliver innovation, inclusion and transformation? *Journal of the Center for Educational Technology*, 6(1) 3-15.

Unisa Open and Distance Learning Policy, (2008) Available from <http://www.unisa.ac.za/default.asp?Cmd=ViewContent&ContentID=23215>. (Accessed May 2016).

Vodacom e-school, (2014). Ace your exams with our Free Educational tool. Department of Basic Education of the Republic of South Africa.

Vodacom, (2015). Ace your exams with our Free Educational tool. Department of Basic Education of the Republic of South Africa.

West, M. & Chew, H. (2014). Reading in the mobile era: A study of mobile reading in developing countries. United Nations Educational, Scientific and Cultural Organisation.

Woolfolk, A. (2010). Educational Psychology. (11th Ed.). New Jersey. Pearson Education International.

Wylie, J. (2015). Mobile learning Technologies for 21st century classroom. Retrieved from Scholastic Inc. www.scholastic.com/browse/article.jsp?i=3754742. (Accessed July 2015).

APPENDICES

Appendix A: Permission request from the Gauteng Department

Request for permission to conduct research at A and B secondary schools.

Title: The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra.

The Director

Gauteng Department of Education

Johannesburg West District (D 12)

Dear Sir/Madam

I, Tendayi Mhlanga am doing a research towards a Master's in Mathematics Education degree at the College of Education at the University of South Africa. I hereby request permission to conduct the study titled; "The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra," at two township secondary schools in your province. I am being funded by the University Of South Africa. My supervisor is Dr Aneshkumar Maharaj. His contact details landline number is +27312601021.

The aim of the study is to determine the impact of integrating smartphone technology on Grade 10 learners' achievement in algebra. In your province, only the Grade 12 learners benefitted from the Gauteng Education Member of Executive Council's roll out of tablets to promote the use of ICT in teaching and learning in this technology era. The Grade 10 learners cannot be denied technology, so smartphones may be integrated for teaching and learning mathematics purposes.

These smartphones are popular amongst them. They have functions and features as those that are found on computers and tablets. It is hoped that this study will make learners use their smartphones for mathematics educational purposes.

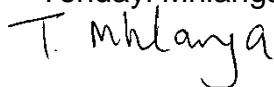
The study will involve two Grade 10 classes from both schools, one class from one secondary school will be a control class and the other class from another secondary school will be an experimental one. Both the classes are going to write a pre-test on algebra under examination conditions. The researcher will mark the test. An intervention programme will be administered to the experimental class. Smartphones will be used for teaching and learning purposes by the experimental on the Microsoft Math website: [https:// math.microsoft.com](https://math.microsoft.com) online twice a week after school hours for six weeks. Each session will take one hour. Then a post-test will be administered to both the control and the experimental classes. The invigilator will be the researcher. She will also mark the test.

If you require any further information, you can contact me on land phone number; +27117945810, e-mail address; mhlangatendayi@yahoo.com and skype name: tendayi.mhlanga.

I hope you will consider the request.

Yours sincerely

Tendayi Mhlanga (Mrs)



..... Signature.

Appendix B: Permission request from School A principal

Request for permission to conduct a study at your secondary school.

Title: The impact of integrating smartphone technology on Grade 10 learners' achievement on algebra.

The Principal

Dear Madam

I, Tendayi Mhlanga am doing a research towards a Master's in Mathematics Education degree at the College of Education at the University of South Africa. I hereby request permission to conduct the study titled; "The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra," at your school. I am being funded by the University Of South Africa. My supervisor is Dr Aneshkumar Maharaj. His landline number is+27312601021.

The aim of the study is to determine the impact of integrating smartphone technology on Grade 10 learners' achievement in algebra. At your school, only the Grade 12 learners benefitted from the Gauteng Education Member of Executive Council's roll out of tablets to promote the use of ICT in teaching and learning in this technology era. The Grade 10 learners cannot be denied technology, so they may use their smartphones for mathematics teaching and learning purposes. These smartphones are popular amongst them. They have functions and features as those that are found on computers and tablets. It is hoped that this study will make learners use their smartphone for mathematics educational purposes.

The study will involve one Grade 10 class from your school as an experimental class. This class will be provided a pre-test on algebra. The invigilator will be the researcher. She will also mark the test. An intervention programme will be administered to the experimental class. The class will use smartphones for algebra

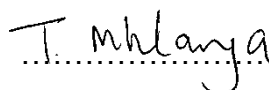
teaching and learning on the Microsoft Math website: <https://math.microsoft.com/> online twice a week after school for six weeks. Each session will take an hour. The class will then write a post-test that will be invigilated by the researcher. She will also mark the test.

If you require any further information, you can contact me on land phone number; 0117945810, e-mail address; mhlangatendayi@yahoo.com and skype name; tendayi.mhlanga.

I hope you will consider the request.

Yours sincerely

Tendayi Mhlanga (Mrs)

..... Signature.

Appendix C: Permission request from secondary school B principal

Request for permission to conduct a study at your secondary school.

Title: The impact of integrating smartphone technology on Grade 10 learners' achievement on algebra.

The Principal

Dear Sir

I, Tendayi Mhlanga am doing a research towards a Master's in Mathematics Education degree at the College of Education at the University of South Africa. I hereby request permission to conduct the study titled; "The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra," at your school. I am being funded by the University Of South Africa. My supervisor is Dr Aneshkumar Maharaj. His landline number is +27312601021.

The aim of the study is to determine the impact of integrating smartphone technology on Grade 10 learners' achievement in algebra.

The study will involve one Grade 10 class from your school as a control class. This class will be provided a pre-test on algebra on a Friday after school hours. It will have algebra lessons with its mathematics teacher according to your school timetable. Then, the class will write a post-test after six weeks. The learners are required to complete each test within an hour. The researcher will invigilate. She will also mark the tests.

If you require any further information, you can contact me on landline phone number; +27117945810, e-mail address; mhlangatendayi@yahoo.com and skype name; tendayi.mhlanga.

I hope you will consider the request.

Yours sincerely

Tendayi Mhlanga (Mrs)

T. Mhlanga Signature

Appendix D: Correspondence seeking permission from mathematics teacher

School A: secondary school mathematics teacher's permission to allow his/her class to participate as an experimental group in a study.

Title of the study: The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra.

Dear Teacher

I am doing a study on the impact of integrating smartphone technology on Grade 10 learners' achievement in algebra. I am doing a Masters' Degree in Mathematics Education at the University of South Africa.

Your principal provided me permission to do this study in your school. I would such as to invite your class to be a special part of my study. The aim of the study is to determine the impact of integrating smartphone technology on Grade 10 learners' achievement in algebra.

This correspondence explains what I would like your class to do. There may be words you do not know in this correspondence. You may ask me or any other person to explain any of the words that you do not know or understand. In this study, your class will write a pre-test on a Friday after school hours. The completion of the test will take an hour. The class will write the test under examination conditions. The researcher will invigilate. She will also mark the test. As an intervention programme, your class will use smartphones for algebra teaching and learning. The learners will be required to login onto the Microsoft Math website: <https://math.microsoft.com> where they will do activities, watch videos, read theories and examples of algebra twice a week after school for six weeks using smartphones. Each session will take an hour. They will also be required to do algebra exercises online. If a learner has a Microsoft/Nokia smartphone, he/she may download the activities using Windows 8.1 whilst he/she is online and then do the activities whilst he/she is offline. The

activities may be conducted anytime and anywhere after school hours. The researcher will be the facilitator. Each learner will receive individual marks for answering mathematics exercises correctly online or offline. This is just a way of encouraging the learners to do Microsoft Math using their smartphones independently. They may form a study group online with their classmates and assess how each member is performing in a friendly way. After the intervention programme, your class will write a post-test that will be invigilated and marked by the researcher. It will take one hour to complete the post-test.

I will write a report on the study, but I will not use your name or your class in the report or say anything that will let other individuals know your name or your class. Your class do not have to be part of this study if you do not want it to take part. If you choose your class to be in the study, you may stop it from taking part at any time. You may tell me if you do not wish your class to answer any of my questions. No one will blame or criticise you and your class. When I completed my study, I shall provide a short talk about certain helpful and interesting thing I would have found out in my study. I shall invite you and your class to come and listen to my talk.

You will be asked to sign the form on the next page. If you have any other questions about the study, you can talk to me or you can call me on +27117945810. Do not sign the form until you have all your questions answered and understood what I would like your class to do.

Researcher's name: Tendayi Mhlanga

Researcher's signature

Teacher's consent

Please complete, delete whatever does not apply, sign and return the form.

.....Tear off here

I.....in capacity as the mathematics
teacher am allowing/ not allowing my class.....

To participate in the study: The impact of integrating smartphone technology on
Grade 10 learners' achievement in algebra.

Signed aton theof.....20...

Teacher.....Full name

.....signature.

Appendix E: Correspondence seeking permission from mathematics teacher

School B: secondary school mathematics teacher's permission to allow his/her learners to participate as a control group in the study.

Title of the study: The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra.

Dear Teacher

I am doing a study on the impact of integrating smartphone technology on Grade 10 learners' achievement in algebra. I am doing a Masters' Degree in Mathematics Education at the University of South Africa.

Your principal has provided me permission to do this study in your school. I would like to invite your class to be a special part of my study.

This correspondence is to explain to you what I would like your class to do. There may be words you do not know or understand in this correspondence. You may ask me or any other person to explain any of the words that you do not know or understand. In this study, your class will write a pre-test on a Friday after school hours. The learners must take one hour to complete the test. The researcher is going to invigilate and mark the test. You are going to teach them algebra lessons according to the school timetable. Then, after six weeks the class is going to write a post –test on algebra on a Friday after school hours. The completion of the test will also take an hour. The post- test will be invigilated and marked by the researcher. Your class will write these tests under examination conditions.

I will write a report on the study, but I will not use your name and your class in the report or say anything that will let other individuals identify you and your class. Your class do not have to be part of this study if you do not want it to take part. If you choose your class to be in the study, it may stop taking part at any time. You may

tell me if your class does not wish to answer any of my questions. No one will blame or criticise your class. You will be asked to sign the form on the next page. If you and your class have any other questions about the study, you can talk to me or you can call me on +27117945810. Do not sign the form until you have all your questions answered and understood what I would like your class to do.

Researcher' name: Tendayi Mhlanga.

Researcher's signature

Teacher's consent

Please complete, delete whatever does not apply, sign and return the form below.

.....Tear up here.

I..... in capacity as the
mathematics teacher am allowing/not allowing my class..... to
participate in the study titled: The impact of integrating smartphone technology on
Grade 10 learners' achievement in algebra.

Signed at..... On the.....day of 20...

Teacher..... Full name

..... signature.

Appendix F: Permission request from parent/guardian at secondary school

A

Parental permission for learners under the age of 18 to participate in a study at a secondary school.

Title: The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra.

Dear Parent/Guardian

My name is Tendayi Mhlanga. I am a Master's student in Mathematics Education at the College of Education at the University of South Africa. I am doing a research with the Grade 10 learners. The study title is "The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra." I am being funded by UNISA.

The aim of the study is to determine the impact of integrating smartphone technology on Grade 10 learners' achievement in algebra. At the secondary school, Grade 12 learners benefitted from the Gauteng Education Member of Executive Council's roll out of tablets to promote the use of ICT in teaching and learning. The Grade 10 learners cannot be denied technology, so, they can use their smartphones since these are popular amongst them. The smartphones have functions and features found in computers and tablets. They can be used for teaching and learning purposes anywhere and anytime because of their portability. Your child will be in experimental class. Smartphones will be used for algebra teaching and learning to the class.

Most learners use their smartphones for communicating non-educative things on social media. It is hoped that this study will make learners use their smartphones for educational purposes. If you allow your child to participate in this study, he/she will be learning the algebra content on the Microsoft Math website,

<https://math.microsoft.com> using his/her smartphone. He/she will also be required to write a pre-test and a post-test. The study will take place during the first term of 2016 twice a week after school for six weeks. Each after school session will last for one hour. The whole study will take six weeks.

Your child's name and identity will be kept completely confidential at all times in all academic writing about the study, your child's individual privacy will be maintained in all published and written data resulting from the study.

Your child's participation in this study is voluntary. He/she may decline to participate or to withdraw from participation at any time. The withdrawal or refusal of your child to participate will not affect his/her relationship with the school. You can agree to allow your child to be in this study, now and then changing your mind later without penalty. In addition to your permission, your child must agree to participate in the study. If your child does not agree to participate he/she will not be included in this study, and there will be no penalty. Can you kindly discuss this with your child?

Neither you nor your child will receive any type of payment for participating in this study. The participant will receive individual marks for answering mathematics activities online correctly as a way of encouraging her to do Microsoft Math using her smartphone independently.

For questions about your rights or any dissatisfaction with any part of this study you can contact anonymously if you wish; Gauteng Department of Education; landline phone number: +2711 3550909; and e-mail inquiries@education.gpg.gov.za or the researcher on +27117945810.

Your child's participation in this study would be greatly appreciated.

Yours sincerely

Tendayi Mhlanga (Mrs).

..... Signature.

Parent/Legal guardian's consent

Parent/Guardian

Please complete, delete whatever does not apply, sign and return the form below.

.....Tear up here.

I in capacity as parent/legal guardian am allowing/not allowing my child in Grade 10 to participate in the study titled: The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra. Tendayi Mhlanga will conduct the research during the first term of 2016. My child is aged 14 years/15years/ 16 years/17years.

Signed at on the ...day of ... 20....

Parent/legal Guardian

..... Full name.

.....Signature.

Appendix G: Permission request from parent/guardian at School B

Parental permission for learners under the age of 18 to participate in a study at B secondary school.

Title: The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra.

Dear Parent/Guardian

My name is Tendayi Mhlanga. I am a Master's student in Mathematics Education at the College of Education at the University of South Africa. I am doing a research with the Grade 10 learners at Meadowlands secondary school. The study title is; "The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra," at your school. I am being funded by the University Of South Africa.

The aim of the study is to determine the impact of integrating smartphone technology on Grade 10 learners' achievement in algebra child's name and identity will be kept completely confidential at all times in all academic writing about the study, your child's individual privacy will be maintained in all published and written data resulting from the study. The learners are going to be in the control class. They will write a pre-test on algebra and they are going to have mathematics lessons with their teacher according to the school timetable. After six weeks, they are going to write a post-test on algebra.

Your child's participation in this study is voluntary. He/she may decline to participate or to withdraw from participation at any time. The withdrawal or refusal of your child to participate will not affect his/her relationship with the school. You can agree to allow your child to be in this study, now and then changing your mind later without penalty. In addition to your permission, your child must agree to participate in the study. If your child does not agree to participate she will not be included in this study,

and there will be no penalty. Can you kindly discuss this with your child? Neither you nor your child will receive any type of payment for participating in this study.

For questions about your rights or any dissatisfaction with any part of this study, you can contact anonymously if you wish: Gauteng Department of Education; landline phone number: +2711 3550909; and e-mail address: inquiries@education.gpg.gov.za or the researcher on +27117945810.

Your child's participation in this study would be greatly appreciated.

Yours sincerely

Tendayi Mhlanga (Mrs).

..... Signature.

Parent/Legal guardian's consent

Parent/Guardian

Please complete, delete whatever does not apply, sign and return the form below.

.....Tear up here.

I in
capacity as parent/legal guardian am allowing/not allowing my child
..... in Grade 10 to participate in the study
titled: The impact of integrating smartphone technology on Grade 10 learners'
achievement in algebra. The research will be conducted by Tendayi Mhlanga during
the first term of 2016. My child is aged 14 years/15years/ 16 years/17years.

Signed at on theday of 20....

Parent/legal Guardian

..... Full name.

.....Signature

Appendix H: Permission request from learner participant at school A

A correspondence requesting assent from learners at A secondary school to participate in a study.

Title of the study: The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra.

Dear learner

I am doing a study on the impact of integrating smartphone technology on Grade 10 learners' achievement in algebra. I am doing a Masters' Degree in Mathematics Education at the University of South Africa.

Your principal has provided me permission to do this study at your school. I would like to invite you to be a special part of my study.

This correspondence is to explain to you what I would like you to do. There may be words you do not know or understand in this correspondence. You may ask me or any other adult to explain any of the words that you do not know or understand. In this study, you will write a pre-test on a Friday after school hours. The completion of the test will take an hour. You will write the test under examination conditions. You will also be required to login onto the Microsoft Math website where you will do activities, watch videos, read theories and examples of algebra twice a week after school for six weeks using your smartphone. Each session will take one hour. You will also be required to do algebra exercises online. If you have a Microsoft/Nokia smartphone, you may download the activities using Windows 8.1 whilst you are online and then do the activities whilst you are offline. The activities may be conducted anytime and anywhere after school hours. You will receive individual marks for answering mathematics exercises correctly online or offline. This is just a way of encouraging you to do Microsoft Math using your smartphone. You may form a study group with your classmates and assess how each member is performing in

a friendly way. Then, you are to write a post-test under examination conditions. The researcher will invigilate that. She will also mark the test.

You may take a copy of this correspondence home to think about my invitation and talk to your parents about this before you decide if you want to be in this study.

I will write a report on the study, but I will not use your name in the report or say anything that will let other individuals know who you are. You do not have to be part of this study if you do not want to take part. If you choose to be in the study, you may stop taking part at any time. You may tell me if you do not wish to answer any of my questions. No one will blame or criticise you. When I have finished with my study, I shall provide a short talk about certain helpful and interesting things I found out in my study. I shall invite you to come and listen to my talk.

If you decide to be part of my study, you will be asked to sign the form on the next page. If you have any other questions about the study, you can talk to me or you can have your parent/guardian call me on +27117945810. Do not sign the form until you have all your questions answered and understand what I would like you to do.

Researcher's name: Tendayi Mhlanga

Researcher's signature

WRITTEN ASSENT

I have read this correspondence that asks me to be part of a study at my school. I have understood the information about my study and I know what I will be asked to do. I am willing to be in the study.

Learner's name

(Print).....

Learner's signature

Date.....

Witness name (Print).....

Witness's signature.....

Date.....

The witness is over 18 years old and present when signed.

Parent/Guardian's name

(Print).....

Parent/Guardian's signature.....

Date

Researcher's name: (Print).....

Researcher's signature

Date

Appendix I: Permission request from learner participant at school B

A correspondence requesting assent from learners at B secondary school to participate in a study.

Title of the study: The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra.

Dear learner

I am doing a study on the impact of integrating smartphone technology on Grade 10 learners' achievement in algebra. I am doing a Masters' Degree in Mathematics Education at the University of South Africa.

Your principal has provided me permission to do this study in your school. I would like to invite you to be a special part of my study.

This correspondence is to explain to you what I would like you to do. There may be words you do not know or understand in this correspondence. You may ask me or any other adult to explain any of the words that you do not know or understand. In this study, you will write a pre-test on a Friday after school hours. You are going to have algebra lessons with your mathematics teacher according to your school timetable. Then, after six weeks you are going to write a post –test on algebra on a Friday after school hours. The completion of each test will take an hour. You will write this test under examination conditions. The researcher will be the invigilator and the marker.

You may take a copy of this correspondence home to think about my invitation and talk to your parents/guardians about this before you decide if you want to be in this study.

I will write a report on the study, but I will not use your name in the report or say anything that will let other individuals know who you are. You do not have to be part of this study if you do not want to take part. If you choose to be in the study, you may stop taking part at any time. You may tell me if you do not wish to answer any of my questions. No one will blame or criticise you.

If you decide to be part of my study, you will be asked to sign the form on the next page. If you have any other questions about the study, you can talk to me or you can have your parent/guardian call me on +27117945810. Do not sign the form until you have all your questions answered and understand what I would like you to do.

Researcher' name: Tendayi Mhlanga.

Researcher's signature

WRITTEN ASSENT

I have read the correspondence that asks me to be part of a study at my school. I have understood the information about my study and I know what I will be asked to do. I am willing to be in the study.

Learner's name:

(Print).....

Learner's signature

Date.....

Witness name:

(Print).....

Witness signature.....

Date.....

The witness is over 18 years old and present when signed.

Parent/Guardian's name

(Print).....

Parent/Guardian's signature.....

Date

Researcher's name:

(Print).....

Researcher's signature:

Date

Appendix J: Pre-test and post-test with memorandum

Pre-test and Post-test with memorandum

Date:

Time: 1 Hour

Marks: 50

Instructions

- Answer all the questions.
- Write neatly and legibly.
- Show all the necessary work.
- Do not write your real name.
- Use a provided number as your pseudo name.
- You must use the same pseudo name on both the pre-test and the post-test.

Pseudo name: ...

Research study title: The impact of integrating smartphone technology on Grade 10 learners' achievement in algebra.

Question 1

1.1 A list of Real Numbers is given

1; 5; 3; $0;\sqrt{5}$; π ; $0,\dot{3}$; -4 .

Write down the

1.1.1 Whole numbers (2 marks)

.....

.....

1.1.2 Irrational numbers (2 marks)

.....

.....

1.1.3 Integers (3 marks)

.....

.....

1.2 Round off the decimal numbers correct to the indicated number of places;

1.2.1 7, 34: to one decimal place. (1 mark)

.....

.....

.....

1.2.2 2, 0999: to three decimal places (1 mark)

.....

[9 marks]

Question 2

Simplify fully

2.1 $(x - 4)(x + 7)$ (2 marks)

.....

.....

.....

.....

.....

2.2 $(x - 2)(x^2 + 2x + 4) - \frac{7}{2}(2x^3 - \frac{16}{7})$ (5 marks)

.....

.....

.....

.....

.....

2.3 $\frac{6^x \cdot 49^x}{14^x \cdot 9^x} \div \frac{7^x}{3^x}$ (5 marks)

.....

.....

.....

.....

.....

2.4 $\frac{2}{x+2} - \frac{1}{x-3}$ (3 marks)

.....

.....

.....

.....

[15 marks]

Question 3

Factorise fully:

3.1 $ab + 4a^2d^2x^3$ (2 marks)

.....

.....

3.2 $x^2 - 2x - 15$ (2 marks)

.....

.....

.....

.....

.....

.....

.....

3.3 $xy + 3y - 2x - 6$ (3 marks)

.....

.....

.....

.....

.....

3.4 $a^3 + 125y^3$ (2 marks)

.....

.....

[9 marks]

Question 4

Consider the following linear number pattern: 2; 7; 12; 17 -----
 -

4.1 Determine the n^{th} term and hence the 199^{th} term. (6 marks)

.....

.....

.....

.....

.....

.....

[6 marks]

Question 5

5.1 Solve for:

5.1.1 $x^2 + 7x = -12$ (3 marks)

.....

.....

.....

.....

.....

.....

.....

5.1.2 $-2x + \frac{x}{5} \geq 18$ (4 marks)

.....

.....

.....

.....

.....

5.2 The sum of two numbers x and y is seventeen. (4 marks)

It is further given that $3x - 2y = 6$.

Determine the values of x and y .

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

[11 marks]

TOTAL [50 marks]

MARKING MEMORANDUM

Question 1

1.1.1	Whole Numbers = $\{3,0\}$	✓ ✓ answer
1.1.2	Irrational Numbers = $\{\sqrt{5}, \pi\}$	✓ answer ✓
1.1.3	Integers = $\{3, 0, -4\}$	✓ ✓ ✓ answer
1.2.1	$7,34 \approx 7,3$ (to one decimal place)	✓ answer
1.2.2	$2,0999 \approx 2,100$ (to three decimal places)	✓ answer

[9 marks]

Question 2

2.1	$(x - 4)(x + 7) = x^2 + 7x - 4x - 28$ $= x^2 + 3x - 28.$	✓ expanding ✓ answer
2.2	$(x - 2)(x^2 + 2x + 4) - \frac{7}{2}(2x^2 - \frac{16}{7})$ $= x^3 + 2x^2 + 4x - 2x^2 - 4x - 8 - 7x^3 + 8$ $= x^3 - 7x^3 + 2x^2 - 2x^2 + 4x - 4x - 8 + 8$ $= -6x^3.$	✓ Expanding ✓ ✓ Grouping like terms ✓ Simplifying ✓ answer

2.3	$\frac{6^x \cdot 49^x}{14^x \cdot 9^x} \div \frac{7^x}{3^x} = \frac{(3 \cdot 2)^x \cdot (7^2)^x}{(7 \cdot 2)^x \cdot (3^2)^x} \times \frac{3^x}{7^x}$ $= \frac{3^x \cdot 2^x \cdot 7^{2x}}{7^x \cdot 2^x \cdot 3^{2x}} \times \frac{3^x}{7^x}$ $= 1.$	<ul style="list-style-type: none"> ✓ exponential form ✓ multiplication sign ✓ reciprocal ✓ common factors ✓ answer
-----	---	---

2.4	$\frac{2}{x+2} - \frac{1}{x-3} = \frac{2(x-3) - (x+2)}{(x+2)(x-3)}$ $= \frac{2x - 6 - x - 2}{(x+2)(x-3)}$ $= \frac{x - 8}{(x+2)(x-3)}$	<ul style="list-style-type: none"> ✓ LCD ✓ numerator ✓ answer
-----	--	--

[15 marks]

Question 3

3.1	$ab + 4a^2d^2x^3 = a(b + 4ad^2x^3)$	<ul style="list-style-type: none"> ✓ factorisation ✓
3.2	$x^2 - 2x - 15 = x^2 - 5x + 3x - 15$ $= x(x - 5) + 3(x - 5)$ $= (x - 5)(x + 3)$	<ul style="list-style-type: none"> ✓ Factors ✓
3.3	$xy + 3y - 2x - 6 = y(x + 3) - 2(x + 3)$ $= (x + 3)(y - 2)$	<ul style="list-style-type: none"> ✓ Factorisation ✓ Factors ✓
3.4	$a^3 + 125y^3 = (a^2 + 5)(a^2 - 5ay + 25y^2)$	<ul style="list-style-type: none"> ✓ Factorisation ✓

[9 marks]

Question 4

Method 1

<p>4.2.1</p> $T_{n=bn+c}$ $b = 5$ $T_1 = 5.1 + c$ $2 = 5 + c$ $2 - 5 = c$ $-3 = c$ $\therefore T_n = 5n - 3$ $T_{199} = 5.199 - 3$ $= 995 - 3$ $= 992$	<ul style="list-style-type: none"> ✓ Correct formula ✓ Common difference ✓ Constant term ✓ n^{th} term ✓ Correct substitution ✓ answer
--	---

[6 marks]

Method 2

Original pattern	2	7	12	17
Multiples of b= 5	5	10	15	20
Difference between original pattern and multiples of 5	-3	-3	-3	-3

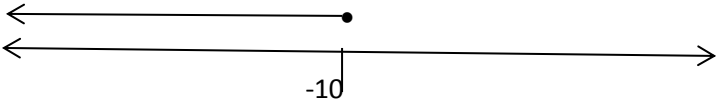
$$C = -3, T_n = bn + c \therefore T_n = 5n - 3$$

$$T_{199} = 5.199 - 3$$

$$= 995 - 3$$

$$= 992$$

Question 5

5.1.1	$x^2 + 7x = -12$ $x^2 + 7x + 12 = 0$ $(x + 3)(x + 4) = 0$ $x + 3 = 0$ or $x + 4 = 0$ $\therefore x = -3$ or $x = -4$	<ul style="list-style-type: none"> ✓ standard form ✓ factors ✓ values of x
5.1.2	$-2x + \frac{x}{5} \geq 18$ $-10x + x \geq 90$ $-9x \geq 90$ $\frac{-9x}{-9} \leq \frac{90}{-9}$ $x \leq -10$ 	<ul style="list-style-type: none"> ✓ Multiply each term by 5 ✓ Divide by -9 ✓ ≤ -10 ✓ Number line
5.1.3	$x + y = 17$A $3x - 2y = 6$B $x = 17 - y$C Substitute C into B $3(17 - y) - 2y = 6$ $51 - 3y - 2y = 6$ $-5y = -45$ $y = 15$ Substitute $y = 15$ in C $x = 17 - 15$ $x = 2$	<ul style="list-style-type: none"> ✓ $x = 17 - y$ ✓ Substitution ✓ $y = 15$ ✓ $x = 2$

(11 marks)

TOTAL: 50 Marks

Appendix K: Examples of online activities done by the experimental group

Examples of online algebra exercises levels that were done by the experimental group. Learners who did not how to solve certain problems were free to click:

Show hint and read theory and examples online before they answered questions.

Sub-topic: Rational and irrational numbers and algebraic products

LEVEL 1

Question 1/3

Worth 10 marks level 1

Between which two integers does $\sqrt[3]{9}$ lie?

Answer with the smaller integer first and in the form: a, b

Submit

Show hint.

Read theory and examples.

Question 2/3

Worth 10 marks level 1

Is the number 5 a rational or irrational number?

Answer by writing either rational or irrational

Submit

Show hint.

Read theory and examples

Question 3/3 level 1

Worth 10 marks level 1

$$(2x - 3)(x - 4) =$$

☐ $2x^2 - 5x - 12$

☐ $2x^2 - 11x + 12$

☐ $2x^2 - 11x - 12$

☐ $2x^2 - 11x - 12$

Click inside the box against the correct answer.

Show hint.

Read theory and examples.

Total marks for level 1 [30]

LEVEL 2

Question 1/3

Worth 10 marks level 2

Between what two integers does $\sqrt{2}$ lie?

- ☐ 3 and 4.
- ☐ 0 and 1.
- ☐ 1 and 2.
- ☐ 2 and 3.

Click inside the box against the correct answer.

Show hint.

Read theory and examples.

Question 2/3

Worth 10 marks level 2

Use your calculator to assist you round off π accurate to three decimal places.

- ☐ 3.1416
- ☐ 3.142
- ☐ 3.14
- ☐ 3.141

Click inside the box against the correct answer.

Show hint.

Read theory and examples.

Question 3/3

Worth 10 marks level 2

Between which two integers does $\sqrt[3]{100}$ lie?

Answer in the form: a,b where a is smaller than b.

Submit

Show hint.

Read theory and examples.

Total marks for level 2 [30]

LEVEL 3

Question 1/3

Worth 15 marks level 3

Between which two integers does $\sqrt{64}$ lie?

Answer with the smaller integer first and in the form: a,b

Submit

Show hint.

Read theory and examples.

Question 2/3

Worth 10 marks level 3

Round the number 26.10325 off to two decimal places.

Submit

Show hint.

Read theory and examples.

Question 3/3

Worth 10 marks level 3

Between which two integers does $\sqrt{30}$ lie?

- ☐ 7 and 8
- ☐ 6 and 7
- ☐ 5 and 6
- ☐ 8 and 9

Click inside the box against the correct answer.

Show hint.

Read theory and examples.

Total points for level 3 [35]

LEVEL 4

Question 1/3

Worth 15 marks level 4

Expand the following expression:

$$(2x^2 + 2x - 3)(2x - 1) =$$

☐ $x^2 + 5x + 3$

☐ $x^3 + 3x^2 - 8x + 3$

☐ $2x^3 + 3x^2 - 8x + 3$

☐ $2x^3 + 5x^2 + 12x + 3$

Click inside the box against the correct answer.

Show hint.

Read theory and examples

Question 2/3

Worth 10 marks level 4

Is the number 5 a rational or irrational number?

Answer by writing either the word rational or irrational.

Submit

Show hint.

Read theory and examples.

Question 3/3

Worth 15 marks level 4

$$(5x + 3)^2 =$$

☐ $10x^2 + 30x + 9$

☐ $10x^2 + 15x + 9$

☐ $25x^2 + 9$

☐ $25x^2 + 30x + 9$

Click inside the box against the correct answer.

Show hint.

Read theory and examples.

Total marks for level 4 [4]

LEVEL 5

Question 1/3

Worth 15 marks level 5

Round the number 7.9099 off to an accuracy of three decimal places.

Submit

Show hint.

Read theory and examples.

Question 2/3

Worth 15 marks level 5

Expand $(3x - 1)^2 =$

☐ $9x^2 + 6x + 1$

☐ $9x^2 - 1$

☐ $9x^2 - 6x + 1$

☐ $9x^2 + 1$

Click inside the box against the correct answer.

Show hint.

Read theory and examples.

Question 3/3

Worth 15 marks level 5

$$2x + 3 - (x + 1)(x + 2) = ax^2 + bx + c$$

Find the values of a,b and c.

Answer without any spaces in the form a,b,c

Submit

Show hint.

Read theory and examples.

Total points for level 5 [45]

LEVEL 6

Question 1/3

Worth 15 marks level 6

Round the number 39725142 off to the nearest ten thousand.

Write your answer as a number without any spaces in it.

Submit

Show hint.

Read theory and examples.

Question 2/3

Worth 15 points level 6

$$\text{If } (2x + 7)(x^2 - 3x + 2) = ax^3 + bx^2 + cx + d$$

Find the values of a, b, c, and d.

Answer without any spaces in the form abcd

Submit

Show hint.

Read theory and examples.

Question 3/3

Worth 15 marks level 6

Expand $(3x + 1)^2 =$

☐ $9x^2 - 1$

☐ $9x^2 - 6x + 1$

☐ $9x^2 + 1$

☐ $9x^2 + 6x + 1$

Click inside the box against the correct answer.

Show hint.

Read theory and examples.

Total marks for level 6 [45]

LEVEL 7

Question 1/3

Worth 15 marks level 7

$$\text{If } (2x^2 + 3x - 4)(2x - 1) = ax^3 + bx^2 + cx + d$$

Find the values of a, b, c, and d. Answer without any spaces in the form:
abcd.

Submit

Show hint.

Read theory and examples.

Question 2/3

Worth 15 marks level 7

$$2[3(x - 1) + 2x(x + 3)] = ax^2 + bx + c$$

Find the values of a, b and c. Answer without any spaces in the form abc

Submit

Show hint.

Read theory and examples.

Question 3/3

Worth 20 marks level 7

Simplify the following:

$$(x^2 - 3x + 2)(2x - 4) - [(x^2 - 3x + 2)(x + 3)] =$$

☐ $x^3 + 6x^2 - 9x - 6$

☐ $x^3 + 8x^2 - 11x - 6$

☐ $x^3 + 6x^2 + 13x - 10$

☐ $x^3 - 8x^2 + 17x - 10$

Click inside the box against the correct answer.

Show hint.

Read theory and examples.

Total marks for level 7 [50]

LEVEL 8

Question 1/3

Worth 20 marks level 8.

Prove that $0.123123123123123123\text{-----}$ is rational by rewriting it as a fraction in its simplest form. Write the fraction answer without any spaces in the form m/n .

Submit

Show hint.

Read theory and examples.

Question 2/3

Worth 15 marks level 8.

Round the number 99999.99 off to the nearest ten. Write your answer as a number without any spaces in it.

Submit

Show hint.

Read theory and examples.

Question 3/3

Worth 20 marks level 8

Is the following expression rational or irrational?

$\frac{\sqrt{3} \times \sqrt{12} - 5}{\sqrt{\frac{16}{10}}}$ Answer by writing the word either rational or irrational.

Submit

Show hint.

Read theory and examples.

Total marks for level 8 [55]

LEVEL 9

Question 1/3

Worth 20 marks level 9.

Simplify the following expression:

$$(x^2 - 3x + 2)(2x - 4) - [(x^2 - 3x + 2)(x + 1)] =$$

☐ $x^3 + 6x^2 - 9x - 6$

☐ $x^3 + 6x^2 + 13x - 10$

☐ $x^3 - 8x^2 + 17x - 10$

☐ $x^3 + 8x^2 - 11x - 6$

Click inside the box against the correct answer

Show hint.

Read theory and examples.

Question 2/3

Worth 20 marks level 9.

Simplify the following expression:

$$(x^2 - 3x + 2)(2x - 4) + (x^2 - 3x + 2)(x + 1) =$$

☐ $3x^3 - 12x^2 + 15x - 5$

☐ $x^3 + 6x^2 + 13x - 10$

☐ $x^3 - 8x^2 + 17x - 10$

☐ $x^3 + 8x^2 - 11x - 6$

Question 3/3

Worth 20 marks level 9

Is the following expression rational or irrational?

$$\frac{\sqrt{20} + \sqrt{8}}{\sqrt{5} + \sqrt{2}}$$

Answer by writing either the word rational or irrational.

Submit

Show hint.

Read theory and examples.

Total marks for level 9 [60]

LEVEL 10

Question 1/3

Worth 20 marks level 10

Use appropriate rounding to estimate the value of the following expression:

$$\frac{5.24(2.19 + 3.78)}{3.106}$$

Submit

Show hint.

Read theory and examples.

Question 2/3

Worth 20 marks level 10.

Expand and simplify

$$(3x + 4)(x - 1) - 2(x + 3)(x - 4) =$$

☐ $x^2 + 3x + 20$

☐ $x^2 - 4x - 28$

☐ $x^2 - 4x - 20$

☐ $x^2 + 3x - 28$

Click inside the box against the correct answer.

Show hint.

Read theory and example

Question 3/3

Study the expansion below:

$$[(3x - 2(x + 3))]^2 - 4(x + 1)(2x - 1) =$$

In which step is there a mistake?

Step1

$$(x - 6)^2 - 8x^2 + 4x - 8x + 4$$

Step 2

$$x^2 - 12x + 36 - 8x^2 + 4x - 8x + 4$$

Step 3

$$x^2 - 12x + 12 - 8x^2 - 4x + 4$$

Step 4

$$-7x^2 - 16x + 40$$

Submit

Show hint.

Read theory and examples.

Total marks for level 10 [60]

TOTAL marks for the 10 levels [450]